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A HYBRID III HEADFORM WITH A FRANGIBLE FACIAL INSERT

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PREFACE

This report describes the continued development of an ATD headform designed to accept a frangible facial insert. This study has attempted to confirm the appropriateness of the test device, and its certification procedures, as well as to demonstrate its effectiveness as a compliance tool.

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1.0 INTRODUCTION

A headform has been developed which is capable of monitoring for fractures of the principal facial bones on the regions of the nose, the zygoma and the maxilla). The developmental history can be found in Newman and Gallup [1] and Gallup et al [2]. This headform is based on a GM Hybrid III headform with a methylmethacrylate insert representing the above noted bones. The test device is documented in reference [3].

Over the past three years, attempts to improve the overall suitability of the device have proven largely unsuccessful. This has been attributed mainly to problems in the insert manufacturing process as well as deficiencies in the certification procedures.

The principal aim of this study was to continue experimentation with the insert in an attempt to both quantify and where possible, rectify those noted deficiencies. This was addressed by testing each sub-component of the design (as independently as possible), as well as by experimenting and testing the manufacturing and certification process. This allowed for the refinement of the certification procedures and the identification of unacceptable components. To evaluate further the device's applicability in automotive testing, destructive testing was carried out at Biokinetics, at Transport Canada Motor Vehicle Test Center (MVTC) in Blainville, Quebec, and at the Vehicle Research Test Center (VRTC) in East Liberty, Ohio.

2.0 INSERT FABRICATION, CERTIFICATION AND TARGET FRACTURE LEVELS

2.1 Insert Fabrication

A total of 252 facial inserts were produced using the six RTV (Room Temperature Vulcanized) rubber molds described in reference [3]. Methylmethacrylate from four different stock batches was used.

In a previous analysis [4] it had been noted that insert weight diminished with repeated material pours due to mold deformation over time. In an attempt to maintain consistency of the inserts pour dates were changed so that parts were created by alternating the pouring and resting of the molds for two day periods. This provided a more dimensionally stable, although heavier, insert than previously produced. Generally, the insert weights ranged from 76 gm to 80 gm, whereas in the previous test series the weights ranged from 63 gm to 78 gm. Unfortunately, this provided inserts which were out of specification with respect to the previously established weight range (70-76 grams). Since the weight sensitivity of the insert to fracture energy had not been strongly related, it was decided to proceed with the slightly heavy but more uniform parts.

2.2 Insert Certification

The pre-test certification drop height for impacts to the nose had been previously set at 39 cm. Preliminary tests with the typically heavier inserts did not produce fractures at this level and thus did not serve to identify excessively weak pieces. It was thus decided to increase the pre-test certification drop height to 45 cm. At the zygoma no such influence was apparent and the certification drop height was left unchanged at 66 cm.

Twenty inserts were made available to MVTC for barrier crash testing, and ten inserts were delivered to VRTC for steering wheel impact testing. Certification test results can be found in Appendix 'A'.

2.3 Human Cadaver and Facial Insert Fracture Levels

When attempting to match the response of an ATD to biomechanical response data from cadavers, it is customary to recognize the high degree of variability associated with such tests and, rather than try to match specific targets for the desired response, "corridors" of acceptable behaviour are usually chosen. In that the initial targets here were meant to represent lower limits for fracture occurrence, it seems appropriate to assign an upper bound on the acceptable fracture response. To this end, and keeping with customary practice for cadaver data, the initial targets were increased by 20% and the new values became the upper limits for the acceptable response. The selected responses then are as shown.

Table 2.1: Cadaver / Facial Insert Fracture Levels

Region	Cadaver Fracture Energy (J) Ref [5,6]	Corridor Boundaries (J) Ref [2]
Nose	N/A	5.0 - 6.0
Nasion	N/A	6.5 - 7.8
Maxilla	4.9-26.3*	5.5 - 6.6
Zygoma	12.6-20.1**	10.0 - 12.0

* No fracture at 6.9 J
** No fracture at 15.7 J

3.0 TEST APPARATUS AND CALIBRATION

All component testing was performed with a guided free-fall drop frame assembly. The impactor weighs 1.46 kg, and the impacting surface is a 2.5 cm diameter steel rod. An accelerometer is mounted to the impactor to measure impact decelerations, and a velocimeter measured impact velocities.

During previous testing, the impact velocities were thought to be highly dependant on bushing internal diameter. A small study was thus conducted to determine an appropriate bushing diameter. Bushings of three different internal diameters were made. The test matrix consisted of three impacts x three drop heights x three bushing sizes.

Percent decreases from the theoretical impact velocity were calculated (these losses were assumed to be due solely to the friction between the bushings and the guide rods). The results are shown in Figure 3.1.

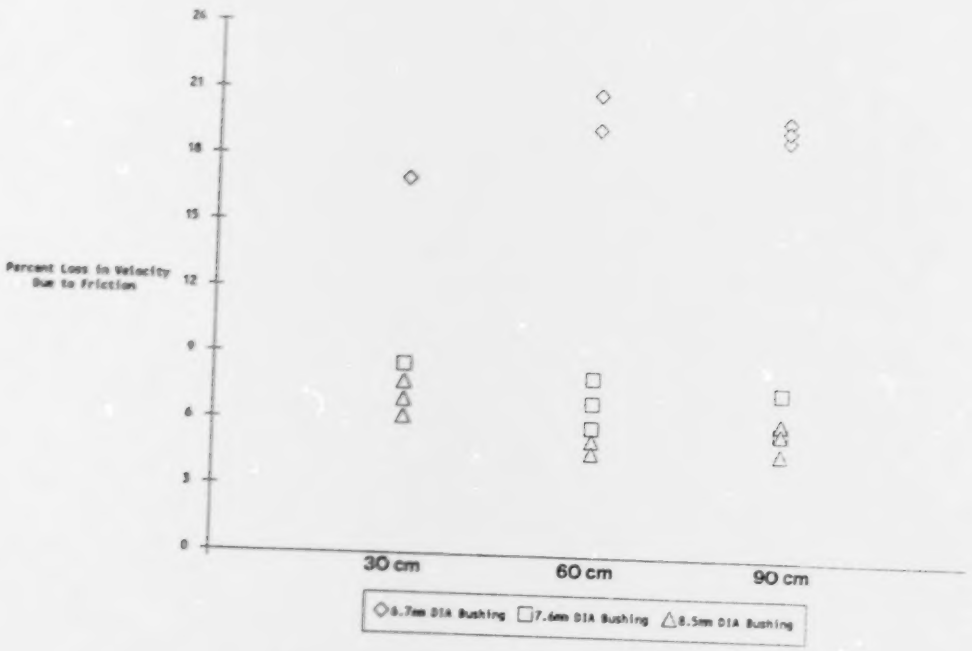

Figure 3.1: Bushing Test Results

The 6.7 mm bushing had approximately twice the frictional influence as the other bushings. The 8.5 mm bushing had slightly less frictional influence than the 7.6 mm bushing, although the excessive clearance between the 8.5 mm bushing and the rods may contribute to variations in eventual impact locations. It was thus decided to use the 7.6 mm bushing for all future testing.

Thirty-three additional calibration tests were conducted from 60 cm drop heights using the 7.6 mm bushings over the 7 month period. Both peak accelerations and impact velocities were recorded for these impacts. Accelerations were monitored to ensure proper accelerometer/data acquisition performance. Drop frame calibration results are presented in Appendix 'B'.

Confidence intervals, at the 95% level, about the velocity and acceleration means were created as certification corridors. The upper and lower bounds for these corridors are indicated in Figures 3.2 and 3.3, as well as the responses upon which they are based.

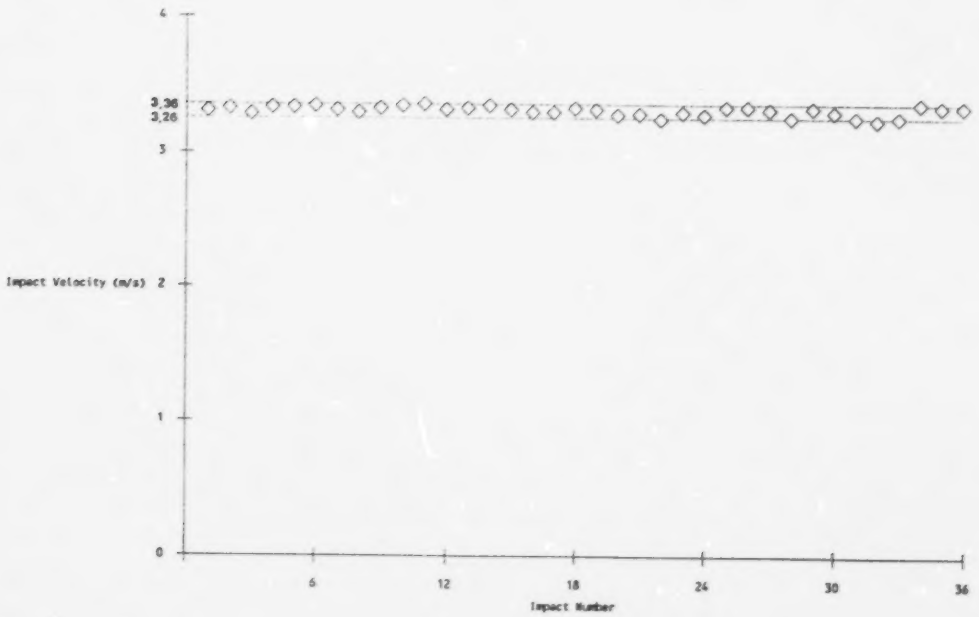

Figure 3.2: Drop Frame Calibrations - Velocity

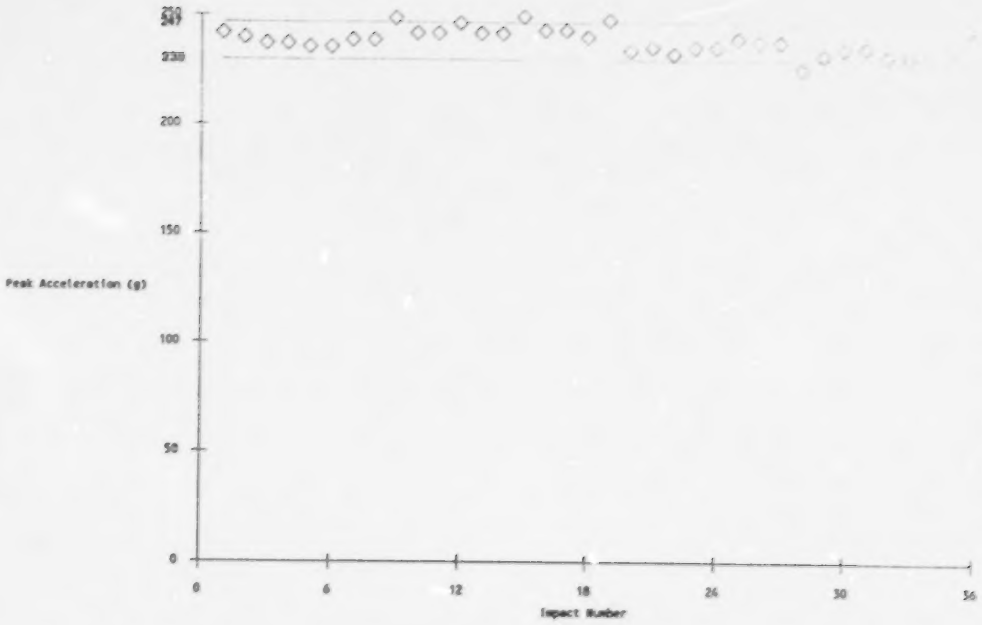

Figure 3.3: Drop Frame Calibrations - Acceleration

In order for the drop frame to be certified, an impact onto the MEP (Modular Elastomer Programmer) calibration pad, from 60 cm, must yield a velocity and a peak acceleration within the specified corridors.

4.0 HYBRID IIIe COMPONENT TESTING

4.1 Interlayer Testing and Analysis

The headform interlayers were evaluated to determine:

a) groups of headforms upon which inserts fracture similarly
b) non-destructive tests by which similar headforms could be identified

Seven headforms were available for testing. In order to evaluate the fracture performance, six frangible facial inserts were fractured on each headform by impacting them at the nose. The inserts were covered with a "standard" 8 mm thick rubber sheet, in order that the influence of the skin covers be eliminated. Impact heights started at 45 cm and were increased in 3 cm intervals until fracture of the insert occurred. The kinetic energy of the striker just prior to contact was recorded as the energy to fracture. This test series was classified as "Destructive Quality Control" or DQC tests. Figure 4.1 shows the fracture energies of the inserts at the nose for this testing. Test results can be found in Appendix 'C'.

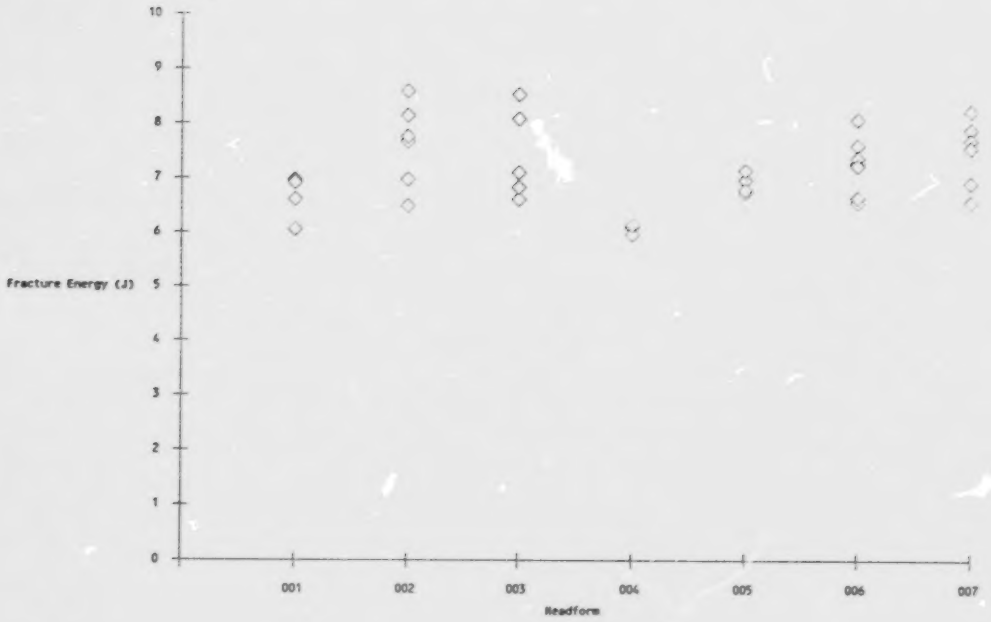

Figure 4.1: Insert Fracture Energies from DQC Testing (All Headforms)

An analysis of variance revealed that inserts tested with headform 004 fractured at significantly[1] lower energy levels than inserts tested with other headforms. No significant differences in fracture levels were identified within the group of other headforms (001, 002, 003, 005 and 007).

[1]Significant levels for this and all other statistical analyses were established at the $\alpha = .05$ level.

As a proposed non-destructive test of interlayer performance, the headforms were impacted with the striker directly on the RTV interlayer at the nose. Drop heights of 51 cm and 30 cm were used. Previous testing had shown a substantial difference in adjusted acceleration[2] between any initial impact and all subsequent impacts (with an impact "recovery" period of 5 minutes). Analysis was thus confined to those impacts following the initial. Each interlayer was impacted a total of four times (including the initial) from each of the two drop heights. These tests were classified as "Interlayer Tests".

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[2] The previous criterion variable for impact testing of this type had been peak acceleration of the impactor for a given drop height. However, slight variations in actual impact velocities in these tests confounded the analysis, necessitating a more appropriate criterion variable. Since acceleration is essentially proportional to velocity, the non-dimensional variable of $gVth/V$ was created, where:

g = peak acceleration (g)

V = impact velocity (m/s)

V_{th} = theoretical impact velocity for the drop height (m/s)

This variable was called adjusted acceleration and will be used for this and subsequent analysis.

Similar trends in relative headform response were observed in both the 30 cm and 51 cm testing. The 30 cm test results will thus not be considered, given that the insert fracture velocities are closer to those obtained in impacts from the 51 cm drop height. Figure 4.2 shows the interlayer responses to 51 cm impacts at the nose in terms of adjusted acceleration.

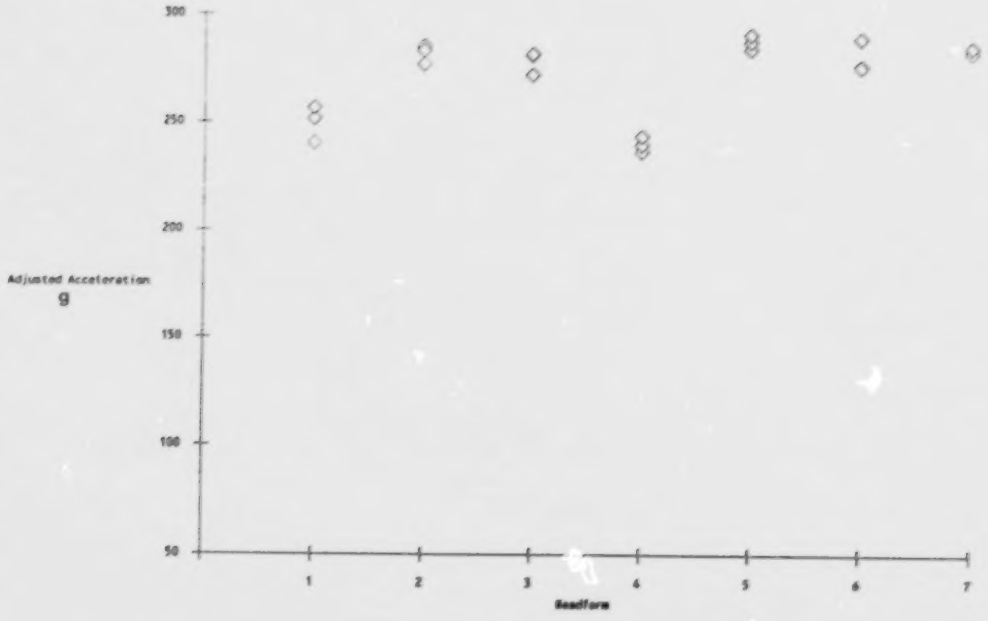

Figure 4.2: Impact Response for Interlayer Testing (51 cm at the Nose)

An analysis of variance was done and it was found that headforms 001 and 004 differed from all other headforms in terms of response to direct impact at the nose. No differences were found within the remaining group of headforms. This was encouraging given that headform 004 was also found to be significantly different from the other headforms in terms of insert fracture levels at the nose. The correlation between adjusted acceleration from the Interlayer Tests (at 51 cm) and insert fracture energies at the nose for all headforms was significant, with $r = .79$.

Interlayer Tests were also conducted at the zygoma[1]. Results are presented in Figure 4.3.

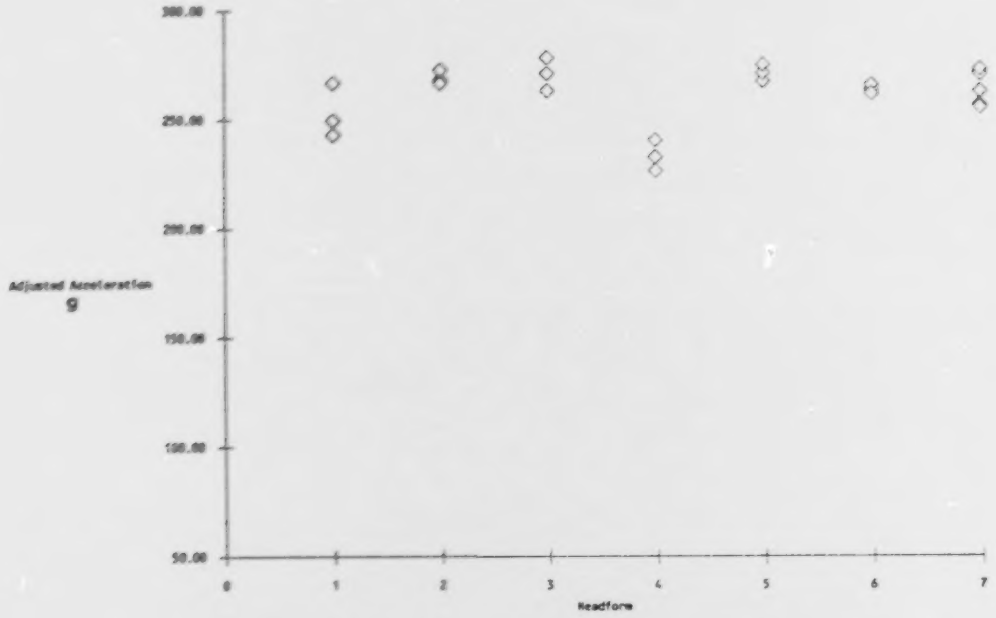

Figure 4.3: Impact Response for Interlayer Testing (51 cm at the Zygoma)

Headforms 001 and 004 were identified as being significantly different in terms of zygoma interlayer response. No DQC tests were conducted at the zygoma, and it is assumed that similar trends to those found in the nose DQC tests would be observed.

Interlayer testing at the nose appears to be a viable means of identifying headforms which might unduly influence insert fracture levels.

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[1]Where not otherwise specified, refers to the left zygoma.

Since headforms 002, 003, 005, 006, 007 were judged identical based on both the DQC and Interlayer Test series, and given that similar trends were observed between these headforms at both impact locations (the nose and the zygoma), it was decided to establish a certification corridor based on the test results obtained for the nose region from the Interlayer Tests.

Upper and lower boundaries of the corridor were determined as the upper and lower bounds of a confidence interval, based on the mean adjusted acceleration values obtained from the five identical headforms. A graphical representation of this corridor is presented in Figure 4.4.

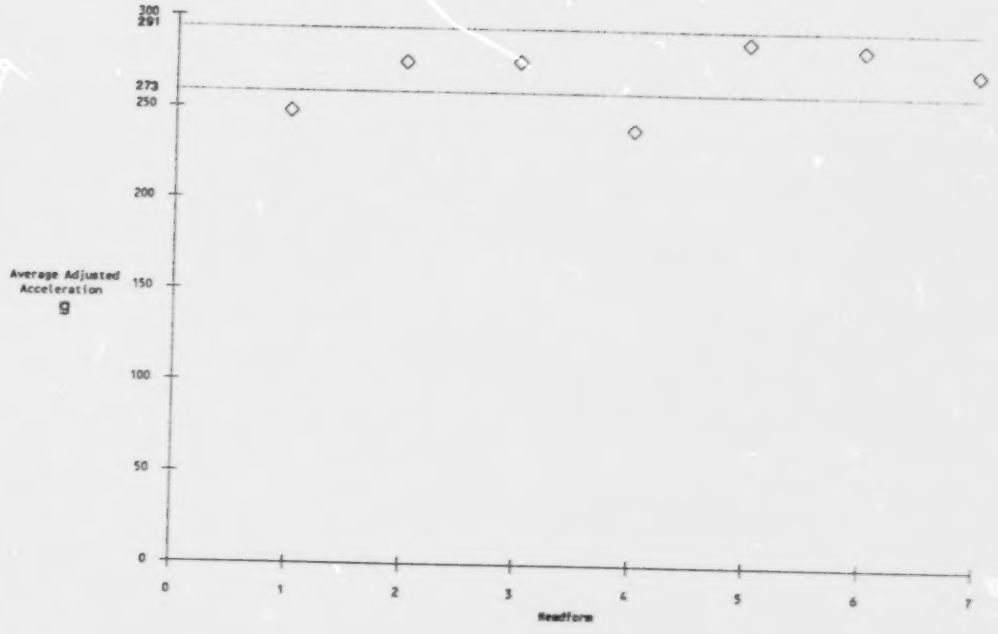

Figure 4.4: Mean Impact Response for Interlayer Testing at 51 cm (Nose) with Certification Corridor

There exists the possibility that one discreet interlayer impact response of a given headform will be unrepresentative of the mean response of that headform, in terms of the certification corridor. The certification protocol will thus use the mean interlayer impact response of the headform, as opposed to data from a single impact. The mean adjusted acceleration of the latter three impacts must be between 273 g and 291 g in order for the headform to be certified.

4.2 Skin Cover Testing and Analysis

In order to determine any possible influences of the skin covers on insert fracture performance, two inserts were fractured at the nose using each of fifteen skin covers, using a certified headform. These tests were classified as "Insert System" tests. The results are shown in Figure 4.5. For presentation, the skin covers have been given the numbers 1 through 17. Specific skin cover numbers can be found in Appendix 'D'.

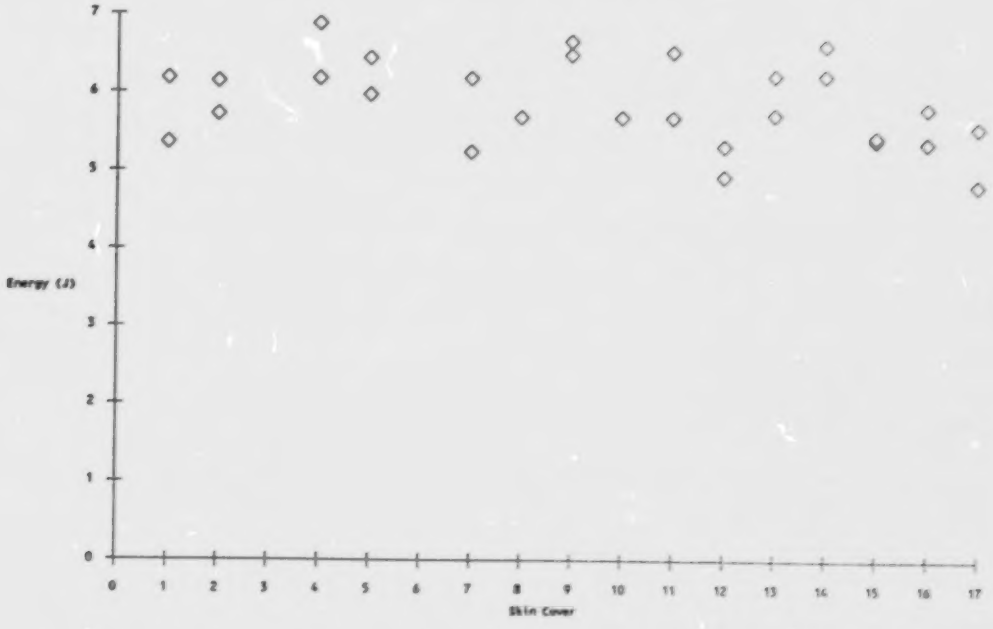

Figure 4.5: Insert Fracture Energies at the Nose
(Insert System Tests - All Skin Covers)

An analysis of variance was done on this data and it was found that no skin cover differed from another in terms of insert fracture performance at the nose.

A smaller subset of six skin covers was tested for insert fracture performance at the zygoma. Twenty-four inserts were fractured using the six skin covers and two certified headforms. Figure 4.6 shows the results of these tests. Complete Insert System test results can be found in Appendix 'E'.

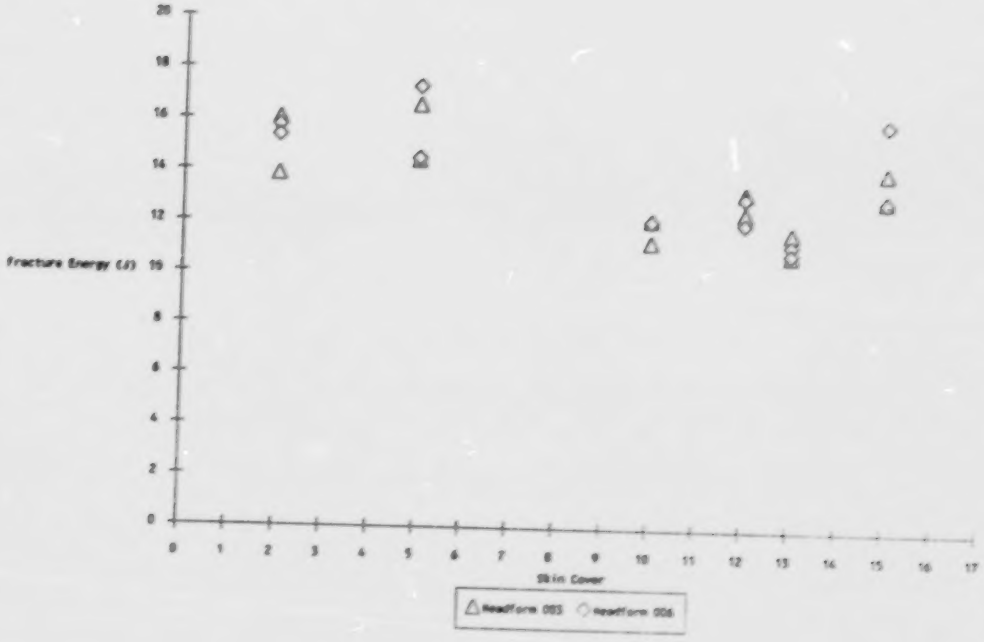

Figure 4.6: Insert Fracture Energies at the Zygoma (Insert System Tests)

Analysis of variance indicated significant differences between skin covers in terms of fracture performance at the zygoma. However, the test by itself does not provide a means to identify those covers that are not acceptable (based on impacts to the zygoma). In fact, the differences observed here may not be entirely attributable to differences in the material or thickness characteristics of the skin covers themselves (or the variability between inserts). They may be simply a function of the more complex unsymmetrical geometry at the zygoma, a possibly more inconsistent fitting of the skin to the headform, less than optimum stress riser holes in the insert at this region, as well as other unknown features unique to this particular location.

In order to determine a controlled, non-destructive test to select appropriate skin covers, two potential types of skin cover certification tests were evaluated. Both used the adjusted acceleration of the impactor when dropped onto the skin cover as a response criterion, but differed in terms of the skin cover support. One, called "Solid Headform" tests, uses a modified Hybrid III skull (for use as the plug for skin cover manufacturing) as support for the skin cover. The other uses a certified, Hybrid IIIe headform, equipped with a metal insert, and is called "Metal Insert" tests.

All seventeen skin covers were impacted at both the nose and zygoma using both test types from one of two drop heights. Both the Solid Headform and Metal Insert tests were conducted from the 51 cm drop height, and 4 impacts were performed for each combination of drop height and location. Impacts to the same location on a given skin cover were conducted at 5 minute intervals, as previous testing had indicated that this was the shortest recovery time possible that would not significantly alter skin cover performance.

Metal Insert skin cover tests were also conducted from 100 cm at the zygoma, since the fractures observed in the Insert System tests at the zygoma were typically associated with drop heights of approximately this level.

As in the Interlayer tests, the response data obtained from the initial

impact to each location on a skin cover were discarded. Only those responses obtained from the 3 last impacts at a specific location on a skin cover were considered for analysis.

In order to evaluate the hypothesis that all skin covers are similar in terms of insert fracture performance at the nose, (as was indicated by the analysis of variance) the Insert System test fracture energies were compared with the Destructive Quality Control fracture energies. The latter used a sheet of 8 mm thick rubber instead of a skin cover as interface between the impactor and the insert. Only results obtained from the five certified headforms were used, and these are presented in Figure 4.7.

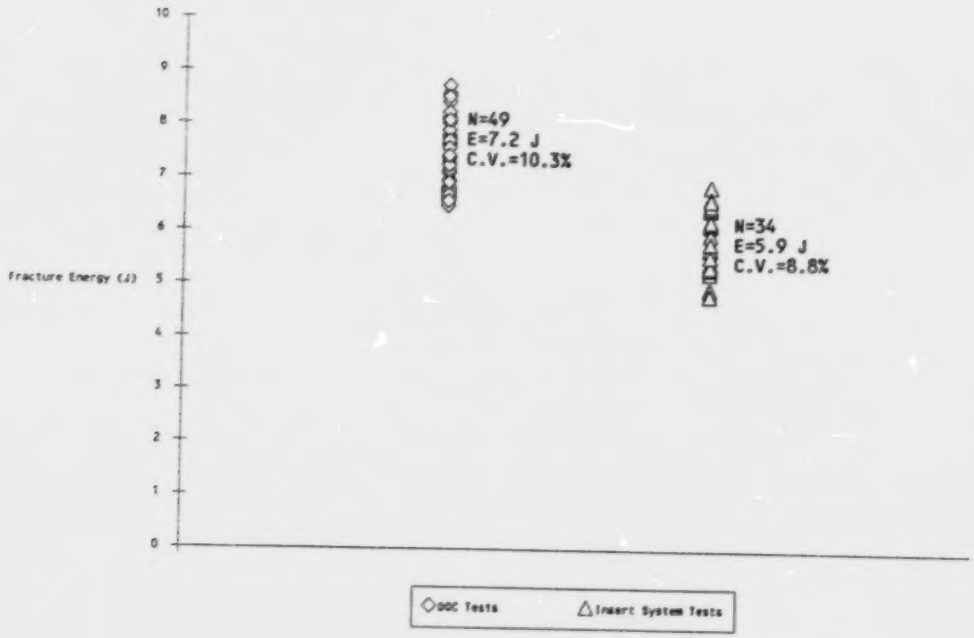

Figure 4.7: Insert Fracture Energies at the Nose (Insert System Tests)

There is slightly more variation in the Destructive Quality Control nose fracture energies than there is in the Insert System test nose fracture energies. It can therefore be concluded that collectively the skin covers are no more variant than a "standard" sheet of rubber in terms of impact response at the nose for these fracture velocities. Thus the majority of insert fracture energy variability at the nose in the Insert System tests cannot be attributed to the skin covers. This conclusion cannot support nor refute the use of either form of skin cover testing at the nose.

In order to determine the nature of the relationship between component test response and fracture performance for all skin covers, adjusted accelerations were correlated with fracture velocities for both component test types. The results are presented in Table 4.1.

Table 4.1: Correlation Coefficients Between Insert Fracture Energy and Skin Response as a Function of Component Test and Drop Height

Support Structure/Drop Height	Nose Fracture	Zygoma Fracture
Solid Headform / 51cm	0.35	0.65
Metal Insert / 51cm	0.39	0.57
Metal Insert / 100cm	N/A	0.78

Since all skin covers found to fracture inserts similarly at the nose, while significant differences were found in skin cover fracture performance at the zygoma, certification procedures at both locations were desirable. Since the solid headform tests did not appear to offer any significant benefits over the Metal Insert tests, and the Metal Insert tests in the future would be easier to replicate at different laboratories, the Metal Insert test protocol was selected to establish the skin cover certification procedures. For the nose, the 51 cm drop height was selected. In the case of the zygoma, the correlation between insert fracture performance and component test responses was stronger for the 100 cm impacts than for the 51 cm impacts. The 100 cm

Metal Insert Test protocol was thus established for skin cover certification at the zygoma.

Figure 4.8 depicts the relationship between skin cover nose fracture performance and impact response to 51 cm Metal Insert tests.

Figure 4.9 shows the relationship between skin cover zygoma fracture performance and impact response to 100 cm Metal Insert tests.

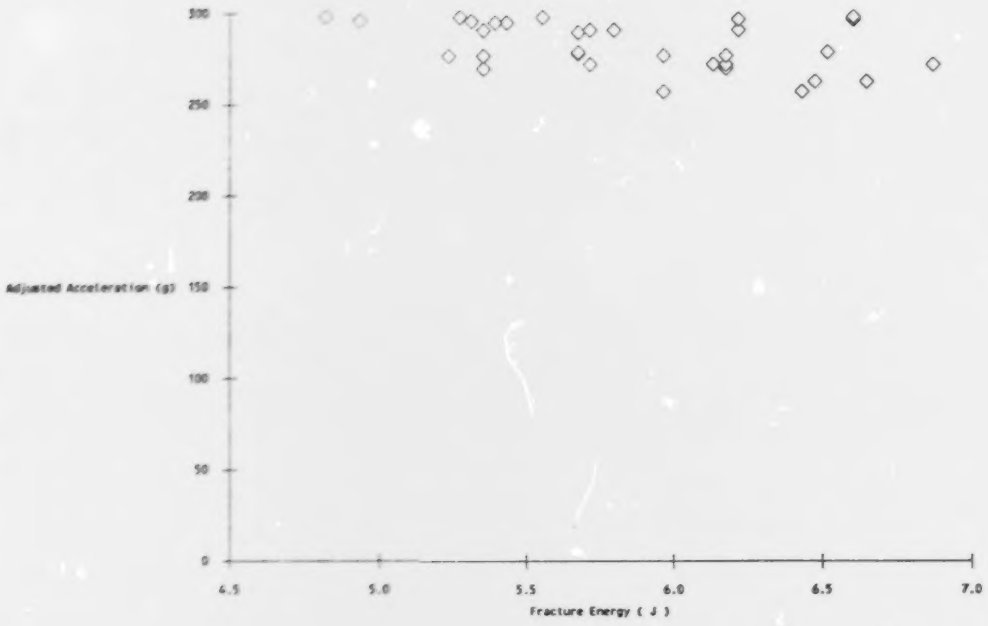

Figure 4.8: Metal Insert (51 cm) Test Mean Normalized Acceleration vs. System Test Fracture Velocity at the Nose

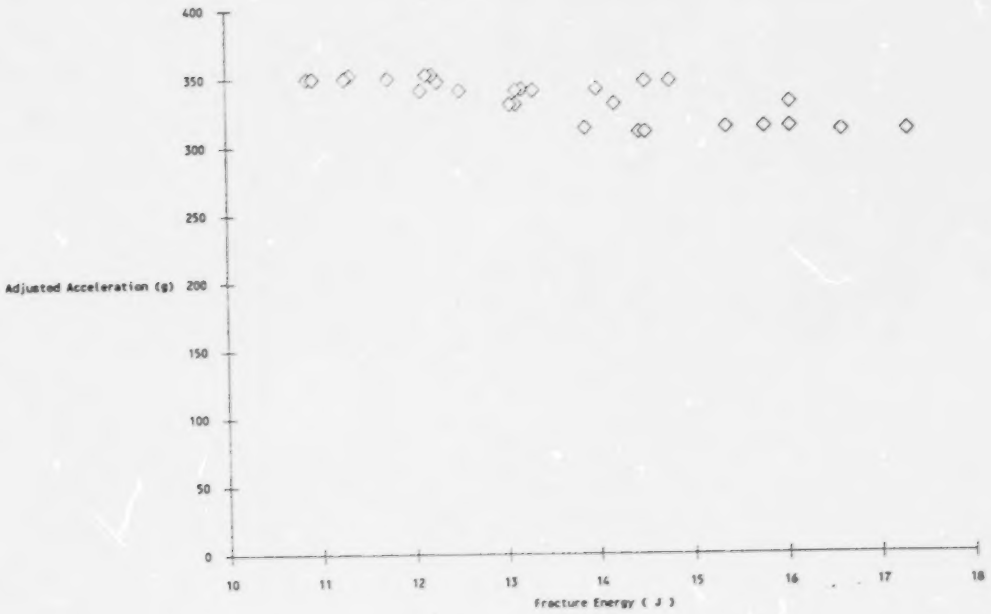

Figure 4.9: Metal Insert (100 cm) Test Mean Normalized Acceleration vs. System Test Fracture Velocity at the Zygoma

Since all tested skin covers were found to fracture inserts similarly at the nose, and did so at levels consistent with the human tolerance range, the certification procedure established must accept all tested skin covers. The upper and lower boundaries of the corridor were established as the confidence interval on the mean corrected response data obtained from the 51 cm Metal Insert Test series for all skin covers.

The selected nose corridor (255 g - 303 g) is shown in Figure 4.10, as well as the mean response of each skin cover tested.

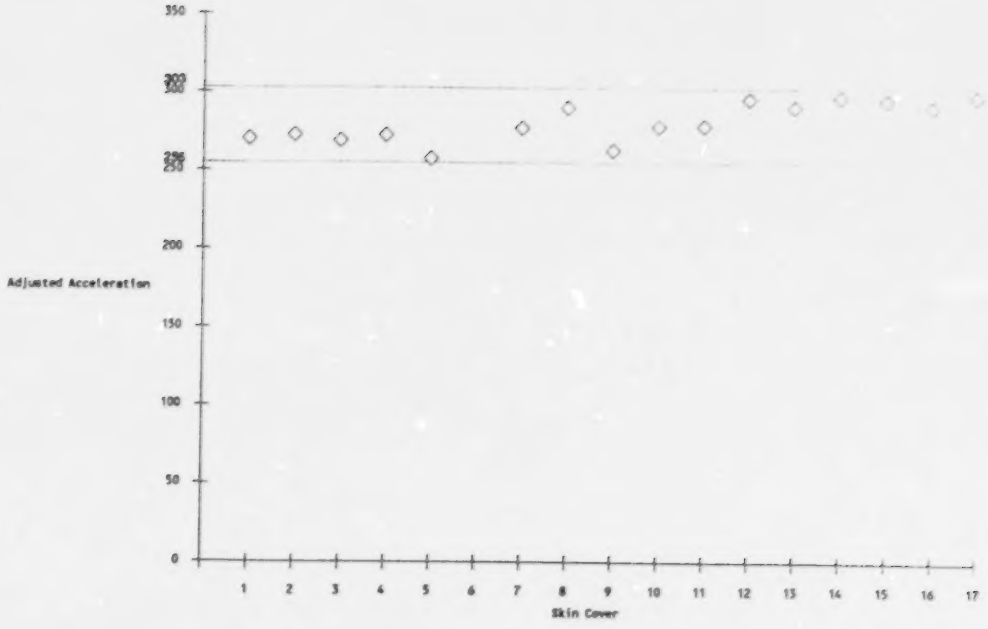

Figure 4.10: Nose Skin Cover Certification Corridor With Metal Insert (51 cm) Test Mean Response

At the zygoma, certain skin covers were found to fracture inserts at a significantly different level than did the others. The overall range of energies to fracture at the zygoma is also larger than the cadaver tolerance range established. A proper certification procedure would eliminate those skin covers whose data contribute to this excessive range. The correlation obtained between zygoma insert fracture performance and Metal Insert test results, while significant, is not strong enough to accomplish this with any mathematical certainty.

A corridor can be established as a confidence interval on the corrected response data obtained only from those skin covers which induced insert fractures approximately in the human target range (10-12 J). This procedure,

while somewhat arbitrary does result in more appropriate eventual energies to fracture at the zygoma. The selected corridor boundaries (337 g - 352 g) are presented in Figure 4.11.

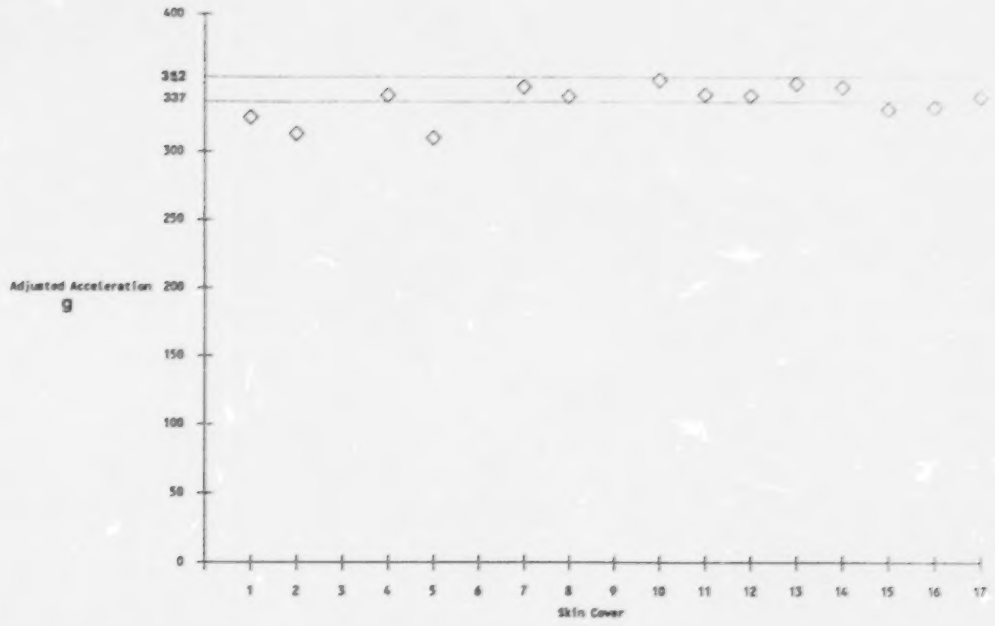

Figure 4.11: Zygoma Skin Cover Certification Corridor with Mean Metal Insert (100 cm) Test Response

Thus, in order for the skin cover to be certified, a skin cover/metal insert/certified headform assembly shall be impacted from 51 cm at the nose four times at five minute intervals. The average adjusted acceleration from the final three impacts must be between 255 g and 303 g. In addition, each skin cover/metal insert/certified headform assembly shall be impacted from 100 cm at the zygoma four times at five minute intervals. The average adjusted acceleration from the final three impacts must be between 337 g and 352 g.

4.3 Frangible Insert Testing

Fracture energies for the Insert System tests at the nose (30 tests) and zygoma (24 tests) were compiled. Additional Insert System tests were conducted at both the nose (4 tests) and zygoma (9 tests), using only certified headforms. System tests were also conducted at the following locations:

Maxilla (8 tests)

Right Maxilla (6 tests)

Right Zygoma (5 tests)

Insert fracture data from the 1988 Reproducibility Study was also compiled, comprising results from the nose (36 tests), zygoma (18 tests), maxilla (3 tests), nasion (2 tests), and the subnasion (3 tests). Only data using those headforms which meet the current certification criteria were compiled. Figures 4.12 and 4.13 present the fracture data by insert region for the 1988 and present (1989) respectively.

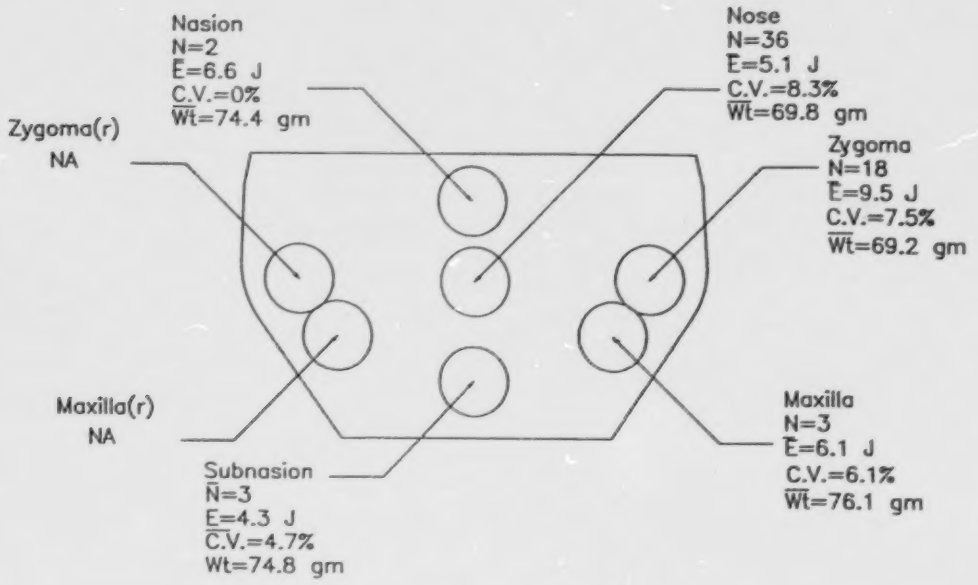

Figure 4.12: 1988 Regional Insert Fracture Data

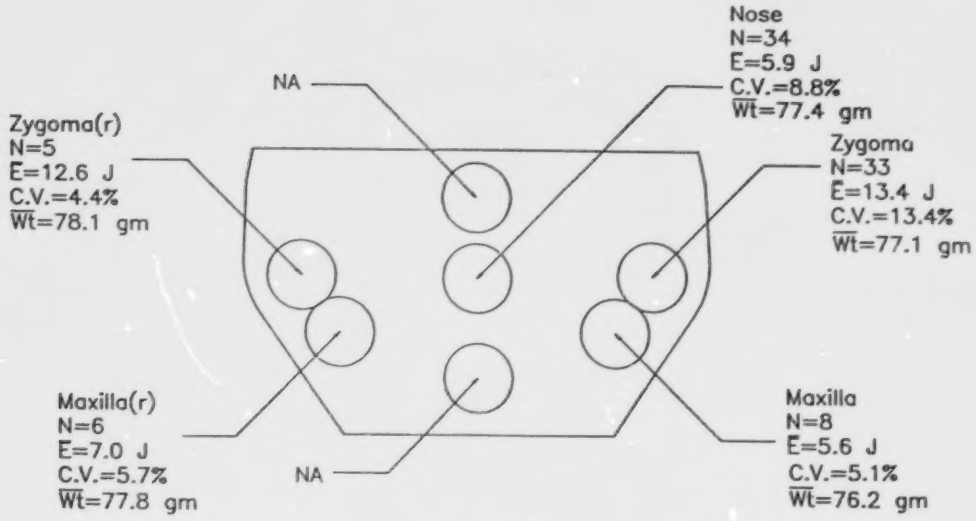

Figure 4.13: 1989 Regional Insert Fracture Data

"Wt" in each of the Figures refers to the average weight of the inserts fractured at the given region.

The energy to fracture data should be evaluated in light of the 3 cm drop height increments used in the testing. This increment corresponds to an energy difference of approximately 0.5 J (calculated from the observed velocities). Thus the given coefficients of variation may be exaggerated somewhat, and any observed differences in the coefficient of variation between otherwise identical data sets can in fact be due to the test protocol only. This is especially true of the smaller data sets, and thus the subsequent analysis will focus primarily on the larger nose and zygoma data sets.

There has been an increase in the mean energy to fracture from 1988 to the present (14.9% and 28.9% for the nose and zygoma, respectively). There has also been an increase in variability of fracture levels, as the coefficient of variation (C.V.) has increased for both the nose and zygoma (from 8.3 to 8.8% and from 7.5 to 13.4%, respectively). Nonetheless, the mean energies to fracture the nose are within the target ranges for both the 1988 and 1989 test series. Those for the zygoma are too high in the current test series and too low in the 1988 test series.

By further limiting the data obtained with skin covers conforming to the revised response corridors reduced the mean energy to fracture at the zygoma by 6.8%, while marginally reducing the C.V. This change had no significant effect on the nose data. Results are presented in Figures 4.14 and 4.15.

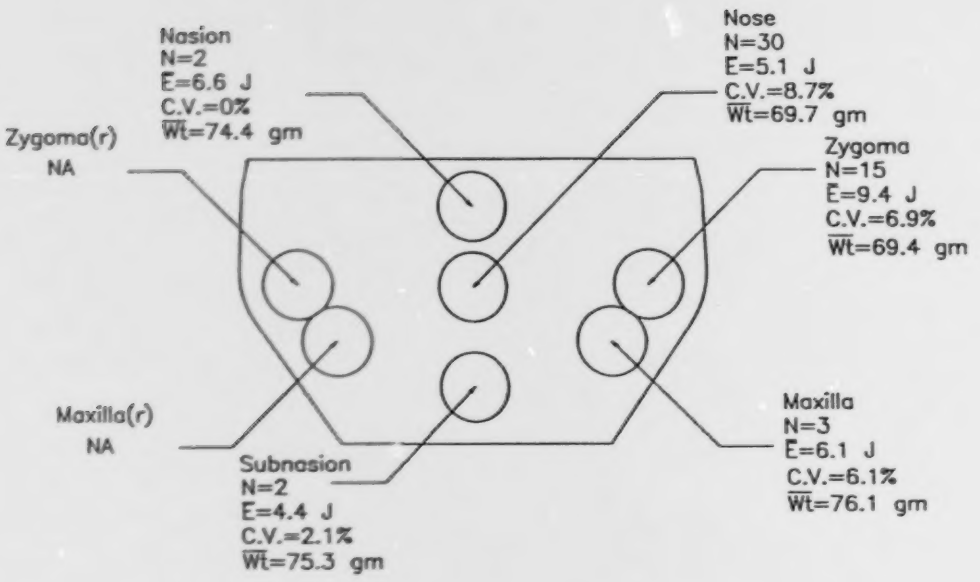

Figure 4.14: 1988 Regional Insert Fracture Data
(Certified Skins Only)

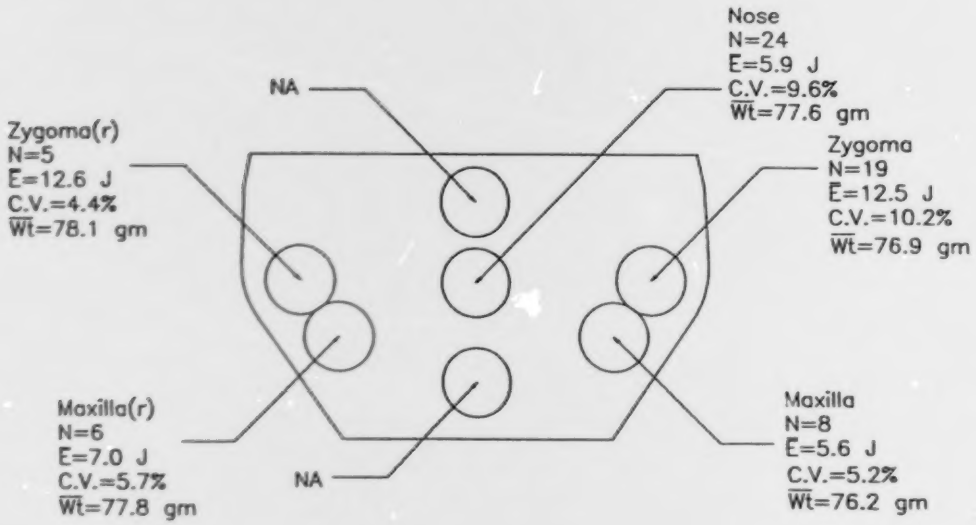

Figure 4.15: 1989 Regional Insert Fracture Data
(Certified Skins Only)

However, this limitation did not entirely reduce the disparity between the 1988 and 1989 results as the fracture energies from the present are still higher than those of 1988 at both the nose and zygoma.

This may be partially explained by the presence of heavier (and hence thicker) inserts in the current study, as compared to the 1988 study. The mean weight of the inserts has increased 11.2% and 10.8% for the nose and zygoma test series' respectively. The relationships between insert weight and fracture energy are depicted in Figures 4.16 and 4.17.

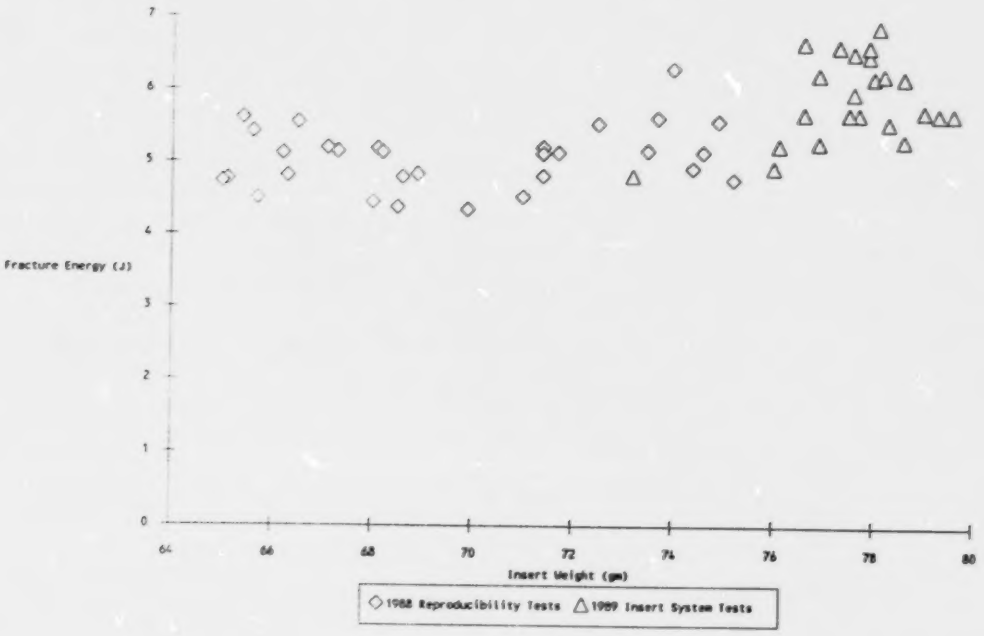

Figure 4.16: Fracture Energy at the Nose vs. Insert Weight

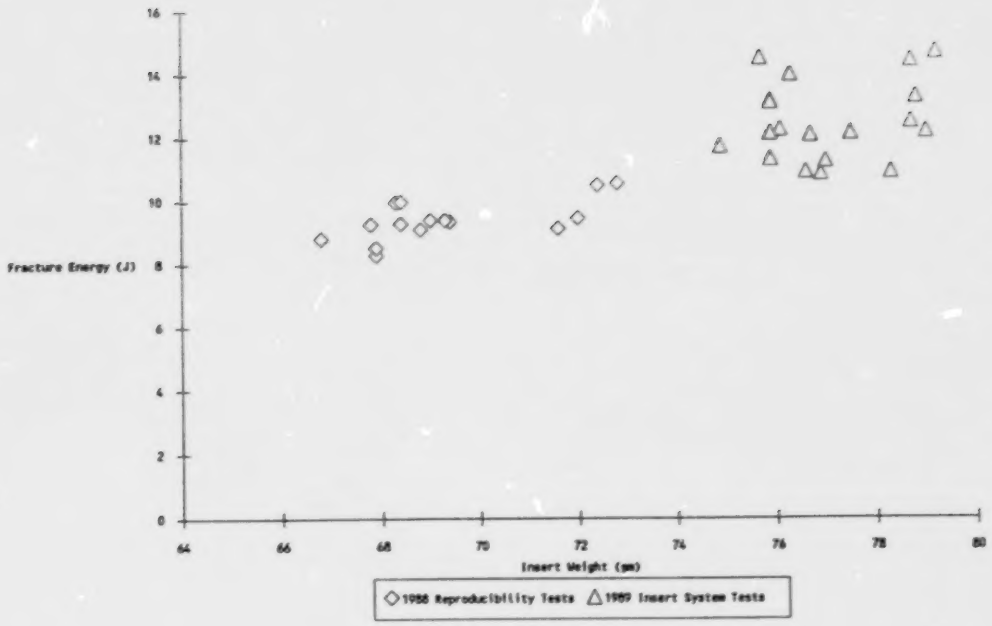

Figure 4.17: Fracture Energy at the Zygoma vs. Insert Weight

The correlation coefficients between insert weight and fracture energy are .65 and .82 for the nose and zygoma combined results from both test series, respectively. These correlations, although significant, are not strong enough to allow the use of insert weights as a control of fracture energies with any mathematical certainty. Thus, there appears to be no justification for establishing an insert weight restriction beyond the observed weight range of 66-80 grams. The variations at the zygoma are real and cannot be explained except in terms of those previously discussed unquantifiable issues (e.g., fit).

Other variables were tested for the existence of a relationship with insert fracture energy. These variables included insert batch no., pour date

and mold number. None proved significant.

4.4 Discussion

This analysis has attempted to quantify the mechanical response characteristics of components and subassemblies that make up the frangible face of the Hybrid IIIe headform. Tests have been conducted to examine the modifications to the skull that provide the compliant backing for the insert. Other tests have examined the modified skin covers in relative isolation. Others have looked at the response of the insert under various controlled impacts. Every plausible means to control test variables has been taken. Yet the variability in system performance, while probably no worse than the variability typical of contemporary ATD's, not only persists, but has actually worsened from the prior studies. The reasons for this are simply not known. However, the following factors no doubt play a role in this situation.

That the skin covers, headforms and test apparatus have some influence on the level of irrepeatability there is little doubt. However, in light of the test results, this influence is marginal. The major problem with the device's level of irrepeatibility lies principally with the insert themselves.

As is clearly illustrated in Figures 4.12 to 4.17, the level of repeatability in the 1989 study has diminished in spite of a more consistent insert (in terms of weight), when compared to the 1988 study.

The irrepeatability may have increased because of mold degradation, and although the weight of the insert may be more consistent, its shape has changed. This change cannot be feasibly quantified.

The irrepeatability may have increased because it is physically more difficult to fit the insert into the headforms. The Hybrid IIIe interlayers are molded using a 1988 insert, and inserts from the current test series differ enough in shape so as to render their placement difficult.

Another reason for this change in repeatability may be a slight change in the impact location. Prior to testing in this study, a new headform placement plate was made, and it now located the headform at a position

that could not be altered from one series of tests to the next. However, the zygoma impact location was slightly different than that previously used (it has been moved laterally approximately 2 mm). Perhaps this *new* impact location on the insert is associated with more random fracture characteristics.

This appears to indicate shape and/or fit as the most likely cause of the problem. The only permanent solution to this problem is in the creation of a permanent mold which could produce consistent, dimensionally stable inserts and which could then be used to create more appropriate Hybrid IIIe headforms.

5.0 NON-DESTRUCTIVE TESTING

5.1 Izod Testing

Izod impact tests were conducted on methylmethacrylate test specimens in an attempt to quantify insert material characteristics. Forty-eight test specimens were tested. These specimens were obtained from the same molds as selected inserts which were tested to fracture. Sixteen inserts were isolated from each of Destructive Quality Control Tests (at the nose) and Insert System Tests (at both the nose and zygoma). The inserts were selected so as to represent the broadest possible range in fracture energies for each test type. It was hoped that the Izod fracture energies from the test specimens would have a strong correlation with the corresponding insert fracture levels.

The Izod test apparatus was modified to accommodate the material and shape of the test specimens, both of which are substantially different from those used in conventional Izod tests. The test bar dimensions are shown in Figure 5.1. The mass of the impacting anvil (as measured at the striker when supported at the pivot) was lowered from 300 to 260 grams in order to be more appropriate for a brittle material such as methylmethacrylate. This lowered the potential impact energy from 1.80 J to 1.56 J. The specimen was impacted on the face opposite to the notch (the so-called "reverse Izod test") so as to mimic the insert failure mechanism somewhat more closely than the "standard" test, which impacts the notched face.

The correlations between Izod fracture energy and insert fracture energy were very weak for each test type: $r = .01, .13, .30$ for the Destructive Quality Control Tests (nose) and insert system tests (nose, zygoma), respectively. These results are consistent with those obtained in the previous (1988) analysis.

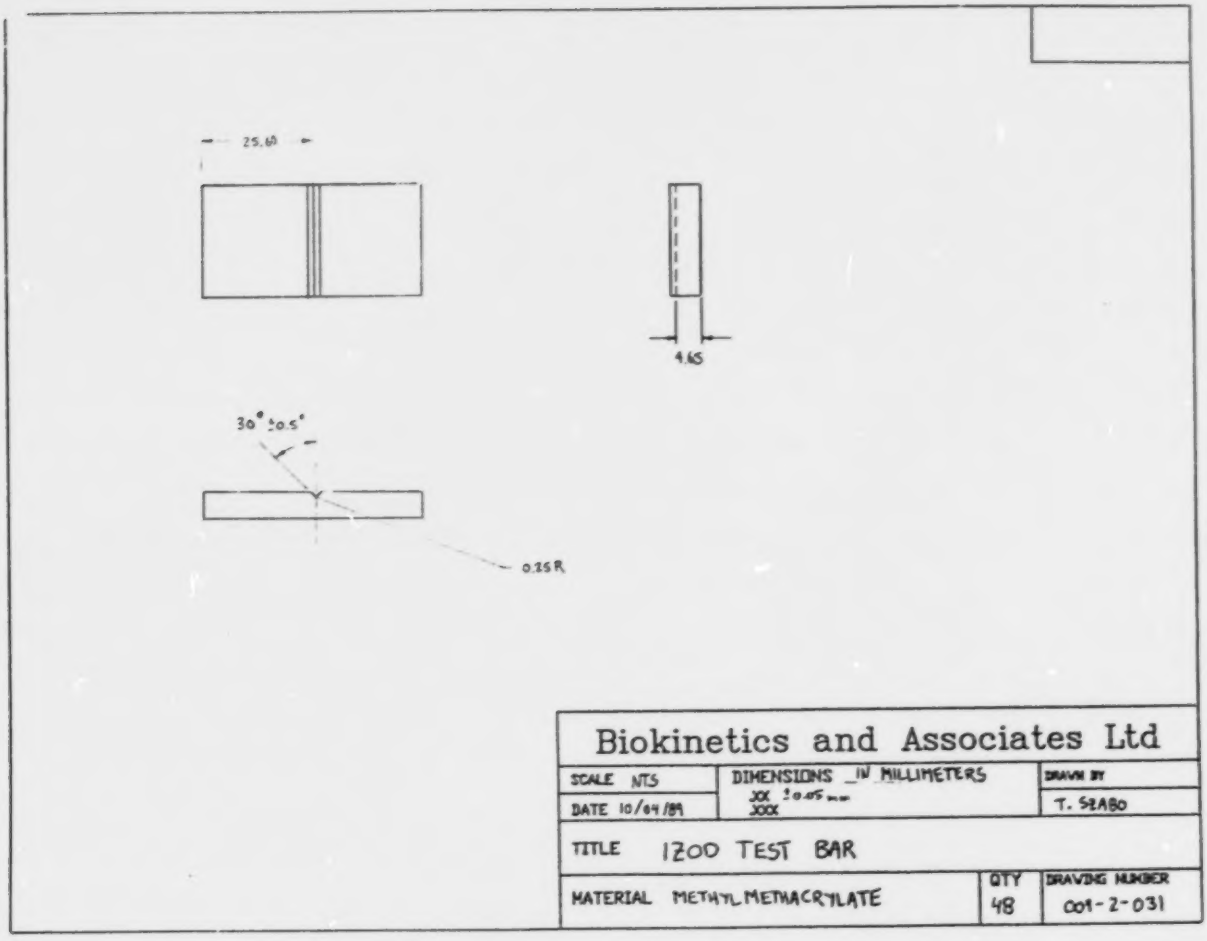

Figure 5.1: Izod Test Bar Dimensions

5.2 Drop Frame Specimen Tests

Test specimens were impacted with the drop frame as an additional attempt to establish a correlate with insert fracture levels. The test specimens were supported by an RTV bed and covered by 80 mm thick rubber. Figure 5.2 shows the RTV test bed. The test protocol called for the specimens to be tested to fracture in the same manner as in the DQC tests (although at different energy levels).

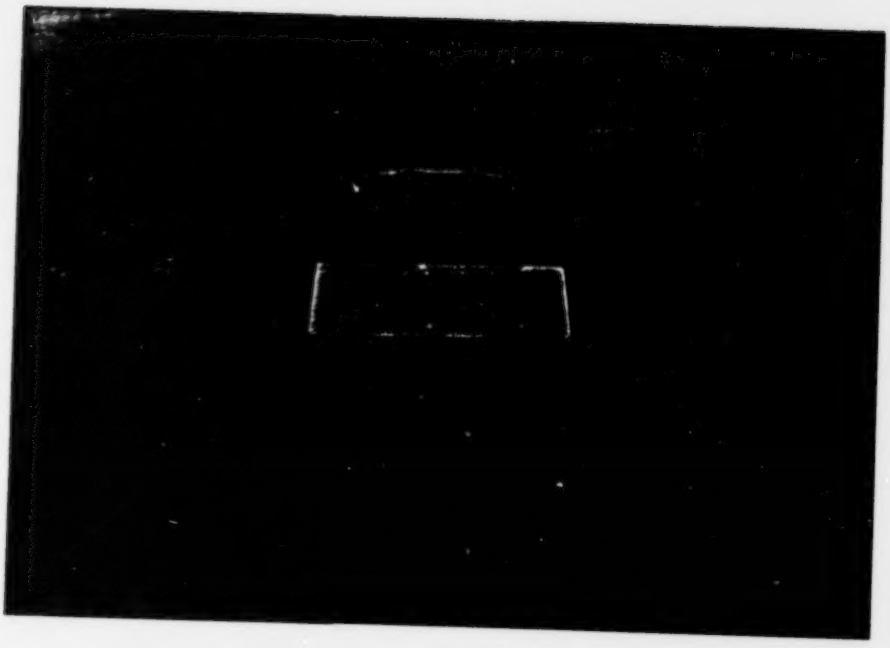

Figure 5.2: RTV Test Bed

In all, 15 specimens were tested, all of which were taken from molds of inserts which were fractured in the DQC test series. It was hoped that this testing would show a stronger correlation with insert fracture levels than the Izod testing since it more closely simulated the actual fracture mechanism seen in the insert tests.

Unfortunately this form of testing did not prove any more useful than the Izod testing, as there was little correlation found between the insert

fracture levels and corresponding test specimen fracture levels (r = .31).

The above test results suggest that the variations found in both insert fracture energy and/or test specimen fracture energy are not predominantly material dependent. It seems more likely that the susceptibility to fracture is dictated by a number of independent factors such as weight, shape, curing procedure, localized material abberations, and localized stress concentrations. Given this variety of potential influences, the existence of one test which could predict insert fracture performance seems highly unlikely and it cannot be too surprising that the test specimen correlations were weak.

5.3 Subsystem Component Testing

It was hoped that some form of non-destructive subsystem testing could be conducted in order to isolate pairs of headforms and skin covers which perform either adequately or poorly in spite of component test results to the contrary. Originally it was planned to use the Metal Insert skin cover testing results for this purpose, however some doubts were raised concerning the sensitivity of testing with the metal insert to differences in interlayers.

To address this issue, a test series using the metal insert covered with the standard sheet of rubber was conducted. Headforms 001, 004, 005, 006, and 007 were subjected to impacts from both 30 cm and 51 cm. Results are presented in Appendix 'F'. The results indicate that all of these headforms respond similarly to these impacts and can thus be considered identical. The DQC results, however, have proven headform 004 to be an inadequate headform in terms of insert fracture levels. Subsystem component testing was thus abandoned, as it seems that any testing incorporating the metal insert will not be sensitive enough to distinguish between headforms.

6.0 REPEAT DESTRUCTIVE QUALITY CONTROL

Three certified inserts were destructively tested to examine the effect that repeated impacts at the nose (at the pre-test certification level) have on eventual fracture levels. All three inserts were impacted 3 times from a drop height of 45 cm. The drop height was then raised by 3 cm until fracture occurred. Rubber was used as the surrogate skin cover.

Fractures occurred at energies of between 7.85 J and 8.65 J. These fracture levels are consistent with those observed in the regular Destructive Quality Control tests (tests without the additional 45 cm impacts). Thus it is unlikely that certification impacts from 45 cm have any affect on eventual insert fracture levels.

7.0 HEADFORM CERTIFICATION

Headforms 002, 003 and 007 were drop tested using two certified skin covers each. Each headform was weighed to ensure that Hybrid III mass specifications were met. Drop tests were performed at the forehead location as per the procedures outlined in Appendix G. Results are presented in Appendix H.

8.0 DEMONSTRATION TESTING

During the course of this project two outside groups utilized the Hybrid IIIe headform for automotive testing.

8.1 Car Crash Tests

Transport Canada Motor Vehicle Test Center have continued to use the Hybrid IIIe headform in full scale frontal barrier crash tests. Since 1987 a total of 28 tests have been conducted with the Hybrid IIIe in a variety of vehicles (2 passengers/26 drivers).

The resultant head accelerations and anatomical/vehicle impact sites are presented in Table 8.1. Thus far only three of the facial inserts have been fractured, all as a result of facial impacts to the hub. All returned unbroken inserts were subsequently tested and found to fracture at the post-test certification level.

Table 8.1: Frontal Barrier Test Results

Vehicle #	TC Test Number	ATD	Contact Region Vehicle/ATD	Peak Resultant Head Acceleration g	Peak Resultant Head Acceleration time(msec)	Insert Fracture
1	*	D	*	96	78	No
2	*	Pass	None	43	72	No
3	*	Pass	None	49	104	No
4	*	D	*	194	87	Yes
5	87-102	D	Hub/forehead	141	83	No
6	87-103	D	Hup top/face	122	98	No
7	87-104	D	Hub/face	197	73	Yes
8	87-109	D	Rim top/forehead	121	82	No
9	87-118	D	Rim/Hub/Face	129	75	Yes
10	87-121	D	Hub/face	91	101	No
11	87-018	D	Hub/rim/chin/forehead	195	80	No
12	87-113	D	Airbag	58	67	No
13	87-128	D	Hub/face	127	89	No
14	87-132	D	Top rim/face	131	69	No
15	87-123	D	Hub/chin	219	77	No
16	87-126	D	Rim/hub/forehead/chi	214	80	No
17	87-127	D	Hub/face	96	78	No
18	88-103	D	Hub/chin	176	87	No
19	88-105	D	Hub/chin	126	69	No
20	88-106	D	Top rim/face	81	89	No
21	88-109	D	Lower rim/chin	77	77	No
22	88-110	D	Hub/Face	87	106	No
23	88-116	D	Hub/Chin	123	65	No
24	88-134	D	Hub/face	86	91	No
25	88-128	D	Rim/hub/face	126	71	No
26	88-124	D	Rim/hub/forehead	91	99	No
27	88-133	D	Hub/forehead	104	95	No
28	88-123	D	Hub/face	130**	77	No

* Data not available
** Peak value estimated from noisy trace

Due to varying camera positions and sight angles, and the location of the vehicle door panels, reliably identifying the dummy head trajectory and the location of the impact with the steering wheel assembly is difficult.

In a typical crash test it was observed that the headform usually makes forehead contact into the upper rim first, after which the chin or face impacts the top of the hub. This however is not always the case. In test 21, for example, the steering wheel was driven upwards, with the upper rim striking the windshield and the chin striking the lower rim. Eight of the tests showed apparent significant impact of the face to the hub with little rim interference. These impacts are typically associated with head accelerations of

approximately 130 g.

The absence of fracture in so many of these tests is of some concern. If in fact the Hybrid IIIe head does monitor for facial bone fracture in a biomechanically faithful manner, then these tests suggest such a device is of limited value. If, on the other hand, the device does not possess sufficient biofidelity to expose facial injury producing mechanisms, it is also of limited value. Given that the former is more likely than the latter, the merits of the device would only be apparent if steering wheel design were to become so poor that facial bone fracture in a standard crash environment became probable. It is not known whether indeed the tests above would produce facial bone fracture to a human occupant.

8.2 University of Wisconsin/VRTC Testing

A series of tests were recently completed at the University of Wisconsin involving 15 cadaver heads. Each cadaver head was rigidly mounted in a halo and ballasted to 6.804 kg. The headform was then dropped from a pre-determined height via a monorail system so that the malar bone of the zygoma impacted the spoke/rim juncture of a 30 degree inclined steering wheel. Nine of the specimens were impacted onto a Sheller-Clifford energy absorbing steering wheel [8] at velocities ranging from 2.68 to 6.93 m/s. Resultant accelerations ranged from 20 g to 75 g, and steering wheel deformations ranged from 19 to 60 mm. The most severe facial fractures were associated with impact velocities in excess of 3.58 m/s.

Six specimens were impacted onto a standard steering wheel at velocities ranging from 2.01 to 3.13 m/s. Resultant accelerations ranged from 20 to 45 g and steering wheel deformation ranged from 8 to 23 mm. The complete test report is given as reference [10]. Table 8.2 shows a summary of the results.

TABLE 8.2: UNIVERSITY OF WISCONSIN CADAVER IMPACT DATA

Specimen #	Sex	Age	Steering Wheel Type	Impact Velocity (m/s)	Impact Energy (J)	Fracture Severity	Res Accn (g)	Steering Wheel Deformation (mm)
5149	M	64	Energy Absorbing	6.93	163.28	4	75	60
7690	M	65	Energy Absorbing	6.93	163.28	4	75	60
5421	M	60	Energy Absorbing	5.59	106.24	4	50	47
5812	M	68	Energy Absorbing	4.47	67.94	4	30	35
4645	F	71	Energy Absorbing	3.58	43.58	4	N/A	N/A
9234	F	65	Energy Absorbing	3.58	43.58	4	25	19
3905	M	57	Energy Absorbing	3.13	33.31	3*	35	20
8250	M	65	Energy Absorbing	3.13	33.31	2**	30	19
7589	F	67	Energy Absorbing	2.68	24.42	0	20	19
8888	M	63	Standard	3.13	33.31	4	45	23
8151	M	69	Standard	2.68	24.42	3***	30	16
5912	M	69	Standard	2.68	24.42	2***	30	10
7643	F	76	Standard	2.24	17.06	4	30	N/A
9274	M	71	Standard	2.24	17.06	4	20	8
6025	M	66	Standard	2.01	13.74	0	20	10

* Sphenoid fracture with no facial bone fracture
** Displaced fracture of left zygomatic arch and maxilla
*** Hairline fracture of the maxilla
Fracture Severity Scale:
0-None
1-Minor
2-Moderate
3-Severe
4-Most Severe

The fracture severity as outlined in the text somewhat unclear. It appears that a severity level of four implies fractures to the zygomatic arch, tripod and maxilla.

A further series of tests was recently carried out at the Vehicle Research Test Center in East Liberty, Ohio. The principal purpose of these tests was to confirm the efficacy of the Hybrid IIIe under conditions that approximate those carried out at the University of Wisconsin.

Nine impact tests utilizing the Hybrid IIIe and either a Sheller-Clifford Safety [8] or Ford Mustang steering wheel were conducted. The testing is fully documented in a VRTC letter report [9].

The complete test results have been extracted and are presented in Table 8.3.

Table 8.3: VRTC Test Results

Drop Height (in)	Impact Velocity (m/s)	Impact Energy (J)	Steering Wheel	Impact Location	Insert ID	Peak Accn (g)	Rim Deformation (in)	Fracture
13.3	2.55	22.11	Ford Mustang	Lower spoke/rim	H-159	53	0.00	no fx.
20.0	3.17	34.17	Sheller-Clifford	Lower spoke/rim	H-158	22	0.38	no fx.
20.0	3.44	40.23	Sheller-Clifford (stripped)	Lower spoke/rim	G-164	22	0.38	no fx.
90.0	6.66	150.81	Sheller-Clifford	Upper rim	E-156	33	3.19	no fx.
90.0	6.71	153.08	Ford Mustang	Upper rim	J-164	88	2.50	no fx.
155.0	8.27	232.54	Sheller-Clifford	Upper rim	I-159	113	4.50	no fx.
155.0	8.14	225.28	Ford Mustang	Upper rim	J-151	96	2.94	no fx.
15.0	2.64	23.70	Ford Mustang	Lower spoke/rim	F-161	31	0.56	no fx.
41.0	4.47	67.94	Ford Mustang	Lower spoke/rim	I-158	41	0.00	no fx.

Direct comparison between the VRTC and Wisconsin results may not be entirely appropriate for two reasons. With the cadaver tests at the University of Wisconsin, all impacts were directed to the zygoma as opposed to the nose impacts conducted at VRTC. Also, all University of Wisconsin tests were directed to the rim/spoke junction of the steering wheel while only 5 tests were done at this location during the VRTC tests.

This analysis will thus be confined to rim/spoke junction impacts. Figure 8.1 shows the data from comparable impacts.

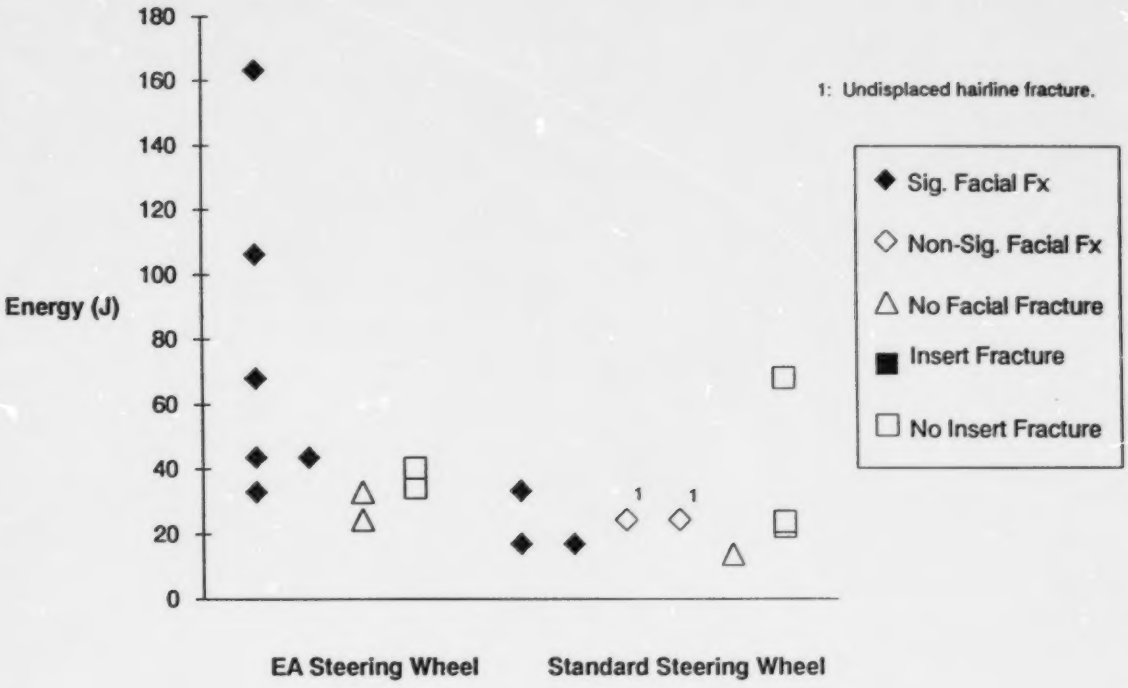

Figure 8.1: Wisconsin/VRTC Test Results

The results above can be interpreted in a number of ways. The no-fracture response of the inserts against the "energy absorbing" steering wheel are not inconsistent with the cadaver results which, in this range of energy, range from "no fracture" to "significant fracture". However, on the standard steering wheel, the cadaver data would suggest that the inserts should have fractured at the energy levels considered. This apparent discrepancy may be the result of differences between the cadaver test protocol and that for the headforms. The precise methodologies were not the same nor were the impact sites. It may also be that the head model (the Hybrid IIIe), designed to replicate certain cadaver test responses, does not replicate, as well, those of the Wisconsin/VRTC tests. Given these limited test results however, one is nevertheless led to the conclusion that the modified headform with the frangible insert is less apt to fracture than a cadaver when impacting an actual steering wheel.

8.3 INRETS Testing

A series of tests comparing the Hybrid IIIe and cadavers was carried out at INRETS by Welbourne et al [13]. The faces of eight cadavers were impacted at the sub-nasal (maxilla) and the nasion with a 25 mm diameter steel bar (meant to approximate a steering wheel rim). An equal number of tests were carried out on the Hybrid IIIe at these two locations. Figure 8.2 shows the results.

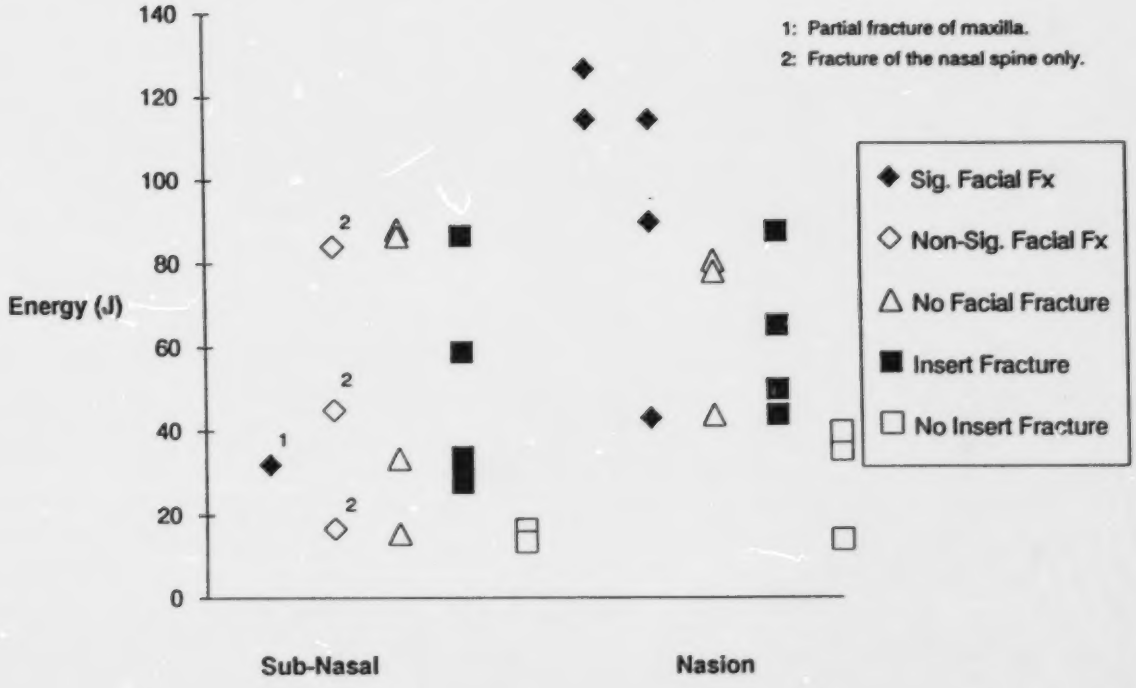

Figure 8.2: INRETS Test Results

At the subnasion, the above results show that cadaver facial bone fracture may or may not occur at the energy levels considered. The frangible insert does not fracture at the lower levels and does at the higher. This response is probably not inappropriate. However, at the nasion, insert fractures always occur where cadaver fractures both do and do not occur. Where no non-fracture cadaver data is recorded, the insert does not fracture. This behaviour suggests that the insert may fracture too easily.

The INRETS test methods are quite different from those at the University of Wisconsin. In the case of the sub-nasal maxilla, no defined threshold was identified from the cadaver tests (unless one only considers the single fracture obtained which occurred at the fracture threshold of the insert).

The results at the nasion suggest that the fracture threshold of the insert may be lower than that for a human. It is doubtful that anyone would conclude on the basis of these data alone, that the response of the insert is necessarily inappropriate. It is noted that the nasion data are at odds with the VRTC test results.

9.0 DISCUSSION

The Hybrid IIIe headform was designed to retain all the features of the Hybrid III and to provide, in addition, the capacity to monitor for facial bone fracture in a biofidelic manner. Of all possibilities, biofidelity in this case meant that fractures at specific locations would occur at energy levels consistent with the then available cadaver data. Within the known limits of contemporary ATD designs practice, this has been accomplished.

To the extent that is possible within the scope of this study, and given the limited degree of sophistication associated with the Hybrid III itself, the certification and quality control procedures that have evolved do provide for a reliable, reproducible test device.

The molding methods could be refined further to improve the reproducibility of the inserts. A first target for improvement would be the mold itself. As has been noted, the duty cycle of an RTV mold, when used with methyl methacrylate, has a pronounced effect on the consistency of the parts it produces. The parts for the current tests were produced at a lower rate than those of previous years and they were heavier. Presumably, they bore a closer relation to the metal master from which the molds were made than those parts produced earlier, yet there was a lack of agreement between the test results and the specifications for these parts. Perhaps the thickness of the metal master is not correct; particularly if this value was selected based on test results of prototypes made from the same type of RTV mold now found to be subject to swelling. It appears that a new, more accurate and stable mold would have to be machined; and expensive proposition given that some experimentation would be required. Initial in-house tests have been conducted with very simple shapes (disks with tapered sides). Teflon and Delrin have been isolated as potential candidate mold materials. More experimentation is required to establish the adequacy of mold release, longevity, duty cycle, stability, etc.

A better understanding of the mechanics at the level of the skin and

the methyl methacrylate face piece/RTV backing (a possible indication of rate sensitivity) might be beneficial. Modern finite element analysis, with the use of non-linear stiffness and hyper-elasticity, might be of assistance in understanding the face piece/backing interface.

The inertial properties of the Hybrid IIIe headform may also require consideration. Although the mass and center of gravity are correct, it may be that differences in mass distribution with respect to the Hybrid III (and to cadaver heads) must now be accounted for.

The target fracture levels for the face piece may require re-evaluation. These were set a number of years ago and were based on the available data which was and remains, limited. The University of Wisconsin and INRETS tests have produced data which are, at this stage, inconclusive but which nevertheless might be used to affect the specifications of the Hybrid IIIe headform. In any case, it would seem that a better understanding of the differences is warranted.

With the experience gained in the present exercise and as additional biomechanical data has become available, such improvements seem feasible. However, the infrequency with which inserts have been observed to fracture in full-scale crash tests leads to the unavoidable conclusion that even the *best* possible faceform may not be particularly useful if in fact no fractures are to be expected in 48 km/h crash test as they are presently conducted.

As a tool for subassembly or component testing however, the device does hold promise. Additional impact tests for a range of simulated crash conditions involving various steering wheel parameters would be appropriate. Design improvements could then be contemplated.

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APPENDIX 'A'

Insert Certification Tests at the Nose

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
326	cert	E150	005	8mm Rubber	nose	45	2.88	6.05	194.22	200.38		Shipped to MVTC February 89
325	cert	E152	005	8mm Rubber	nose	45	2.86	5.97	188.05	195.37		
321	cert	E153	005	8mm Rubber	nose	45	2.75	5.52	DL			
366	cert	E155	005	8mm Rubber	nose	45	2.87	6.01	188.05	194.69		
361	cert	E156	005	8mm Rubber	nose	45	2.82	5.81	184.97	194.90		Shipped to VRTC February 89
672	cert	E159	002	8mm Rubber	nose	45	2.90	6.14	194.22	199.00		
688	cert	E160	002	8mm Rubber	nose	45	2.87	6.01	189.60	196.30		
404	cert	E161	007	8mm Rubber	nose	45	2.83	5.85	188.05	197.44		
352	cert	E162	005	8mm Rubber	nose	45	2.88	6.05	191.14	197.20		
398	cert	E164	007	8mm Rubber	nose	45	2.87	6.01	189.60	196.30		Shipped to MVTC February 89
355	cert	E165	005	8mm Rubber	nose	45	2.86	5.97	189.60	196.98		
659	cert	E167	002	8mm Rubber	nose	45	2.90	6.14	191.14	195.84		
650	cert	E168	002	8mm Rubber	nose	45	2.90	6.14	186.52	191.11	fx	
662	cert	E169	002	8mm Rubber	nose	45	2.91	6.18	194.22	198.32		
667	cert	E170	002	8mm Rubber	nose	45	2.87	6.01	191.14	197.89		
681	cert	E171	002	8mm Rubber	nose	45	2.88	6.05	DL			
1046	cert	E173	006	8mm Rubber	nose	45	2.87	6.01	189.60	196.30		
1070	cert	E174	006	8mm Rubber	nose	45	2.87	6.01	192.68	199.49		
1074	cert	E175	006	8mm Rubber	nose	45	2.88	6.05	188.06	194.03		
1041	cert	E176	006	8mm Rubber	nose	45	2.88	6.05	189.60	195.61		
1027	cert	E177	006	8mm Rubber	nose	45	2.88	6.05	194.22	200.38		
1064	cert	E177	006	8mm Rubber	nose	45	2.86	5.97	191.14	198.58		
1026	cert	E179	006	8mm Rubber	nose	45	2.88	6.05	DL			
1012	cert	E180	006	8mm Rubber	nose	45	2.89	6.10	188.06	193.35		
1054	cert	E181	006	8mm Rubber	nose	45	2.91	6.18	198.85	203.04		
1081	cert	E181	006	8mm Rubber	nose	45	2.88	6.05	186.52	192.44		
1063	cert	E182	006	8mm Rubber	nose	45	2.88	6.05	188.06	194.03		
1397	cert	E183	006	8mm Rubber	nose	45	2.91	6.18	198.85	203.04		
1417	cert	E184	006	8mm Rubber	nose	45	2.89	6.10	195.76	201.27		
1403	cert	E185	006	8mm Rubber	nose	45	2.86	5.97	194.22	201.78		
1408	cert	E186	006	8mm Rubber	nose	45	2.90	6.14	201.93	206.90		
317	cert	F150	005	8mm Rubber	nose	45	2.75	5.52	183.43	198.20		
310	cert	F151	005	8mm Rubber	nose	45	2.85	5.93	DL			
690	cert	F153	002	8mm Rubber	nose	45	2.89	6.10	192.68	198.10		
315	cert	F155	005	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		Shipped to MVTC January 89
327	cert	F156	005	8mm Rubber	nose	45	2.79	5.68	183.43	195.35		Shipped to MVTC February 89
696	cert	F158	002	8mm Rubber	nose	45	2.90	6.14	197.31	202.17		
666	cert	F159	002	8mm Rubber	nose	45	2.88	6.05	194.22	200.38		
687	cert	F160	002	8mm Rubber	nose	45	2.88	6.05	188.06	194.03		
403	cert	F161	007	8mm Rubber	nose	45	2.81	5.76	188.05	198.85		Shipped to VRTC February 89
396	cert	F162	007	8mm Rubber	nose	45	2.76	5.56	181.89	195.82		
673	cert	F165	002	8mm Rubber	nose	45	2.90	6.14	194.22	199.00		
693	cert	F166	002	8mm Rubber	nose	45	2.88	6.05	183.43	189.25		
651	cert	F168	002	8mm Rubber	nose	45	2.88	6.05	181.89	187.66		
663	cert	F169	002	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		
668	cert	F170	002	8mm Rubber	nose	45	2.90	6.14	191.14	195.84		
682	cert	F171	002	8mm Rubber	nose	45	2.90	6.14	189.60	194.27		
1047	cert	F172	006	8mm Rubber	nose	45	2.91	6.18	194.22	198.32		
1034	cert	F174	006	8mm Rubber	nose	45	2.89	6.10	201.93	207.62		
1084	cert	F174	006	8mm Rubber	nose	45	2.90	6.14	184.97	189.52		
1057	cert	F175	006	8mm Rubber	nose	45	2.87	6.01	192.68	199.49		
1069	cert	F176	006	8mm Rubber	nose	45	2.83	5.85	191.14	200.69		
1078	cert	F176	006	8mm Rubber	nose	45	2.89	6.10	183.43	188.59		
1042	cert	F177	006	8mm Rubber	nose	45	2.87	6.01	191.14	197.89		
1013	cert	F180	006	8mm Rubber	nose	45	2.86	5.97	188.06	195.38		

Insert Certification Tests at the Nose

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
1051	cert	F181	006	8mm Rubber	nose	45	2.88	6.05	186.52	192.44		
1032	cert	F182	006	8mm Rubber	nose	45	2.93	6.27	186.52	189.15		
1398	cert	F183	006	8mm Rubber	nose	45	2.90	6.14	197.31	202.17		
1399	cert	F184	006	8mm Rubber	nose	45	2.88	6.05	194.22	200.38		
1404	cert	F185	006	8mm Rubber	nose	45	2.89	6.10	195.76	201.27		
1409	cert	F186	006	8mm Rubber	nose	45	2.90	6.14	198.85	203.74		
313	cert	G151	005	8mm Rubber	nose	45	2.83	5.85	189.60	199.07		Shipped to MVTC January 89
312	cert	G152	005	8mm Rubber	nose	45	DL		186.52			Shipped to MVTC January 89
388	cert	G154	007	8mm Rubber	nose	45	2.83	5.85	184.97	194.21		
324	cert	G155	005	8mm Rubber	nose	45	2.90	6.14	180.35	184.79	fx	
329	cert	G156	005	8mm Rubber	nose	45	2.77	5.60	184.97	198.42		Shipped to VRTC February 89
694	cert	G157	002	8mm Rubber	nose	45	2.97	6.44	184.97	185.05		
389	cert	G158	007	8mm Rubber	nose	45	2.80	5.72	211.17	224.09		Shipped to MVTC February 89
407	cert	G160	007	8mm Rubber	nose	45	2.83	5.85	186.51	195.83		
354	cert	G161	005	8mm Rubber	nose	45	2.85	5.93	191.14	199.28		
393	cert	G162	007	8mm Rubber	nose	45	2.79	5.68	183.43	195.35		
356	cert	G163	005	8mm Rubber	nose	45	2.79	5.68	181.89	193.71		
402	cert	G164	007	8mm Rubber	nose	45	2.75	5.52	178.80	193.19		Shipped to VRTC February 89
658	cert	G167	002	8mm Rubber	nose	45	2.89	6.10	189.60	194.94		
664	cert	G169	002	8mm Rubber	nose	45	2.87	6.01	189.60	196.30		
669	cert	G170	002	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		
655	cert	G171	002	8mm Rubber	nose	45	2.89	6.10	192.68	198.10		
1022	cert	G172	006	8mm Rubber	nose	45	2.90	6.14	191.14	195.84		
1010	cert	G173	006	8mm Rubber	nose	45	2.89	6.10	188.05	193.34		
1053	cert	G175	006	8mm Rubber	nose	45	2.88	6.05	186.52	192.44		
1044	cert	G176	006	8mm Rubber	nose	45	2.90	6.14	188.06	192.69		
1038	cert	G177	006	8mm Rubber	nose	45	2.88	6.05	189.60	195.61		
1048	cert	G178	006	8mm Rubber	nose	45	2.88	6.05	192.68	198.79		
1024	cert	G179	006	8mm Rubber	nose	45	2.92	6.22	172.64	175.68		
1030	cert	G179	006	8mm Rubber	nose	45	2.90	6.14	186.52	191.11		
1062	cert	G182	006	8mm Rubber	nose	45	2.89	6.10	192.68	198.10		
1413	cert	G183	006	8mm Rubber	nose	45	2.92	6.22	201.93	205.48		
1418	cert	G184	006	8mm Rubber	nose	45	2.89	6.10	201.93	207.62		
1400	cert	G185	006	8mm Rubber	nose	45	2.90	6.14	195.76	200.58		
1410	cert	G186	006	8mm Rubber	nose	45	2.90	6.14	198.85	203.74		
319	cert	H150	005	8mm Rubber	nose	45	2.86	5.97	189.60	196.98		Shipped to MVTC February 89
363	cert	H151	005	8mm Rubber	nose	45	2.85	5.93	189.60	197.67		
320	cert	H152	005	8mm Rubber	nose	45	2.85	5.93	188.10	196.11		
322	cert	H153	005	8mm Rubber	nose	45	2.88	6.05	191.14	197.20		
323	cert	H155	005	8mm Rubber	nose	45	2.74	5.48	183.43	198.92		
695	cert	H157	002	8mm Rubber	nose	45	2.88	6.05	180.35	186.07		
391	cert	H158	007	8mm Rubber	nose	45	2.77	5.60	180.35	193.16		Shipped to VRTC February 89
349	cert	H159	005	8mm Rubber	nose	45	2.85	5.93	189.59	197.66		
353	cert	H161	005	8mm Rubber	nose	45	2.84	5.89	188.05	196.75		
394	cert	H162	007	8mm Rubber	nose	45	2.77	5.60	181.89	195.11		
357	cert	H163	005	8mm Rubber	nose	45	2.84	5.89	188.05	196.75		Shipped to MVTC February 89
347	cert	H164	005	8mm Rubber	nose	45	2.88	6.05	191.14	197.20		
401	cert	H165	007	8mm Rubber	nose	45	2.82	5.81	181.89	191.65		
697	cert	H166	002	8mm Rubber	nose	45	2.90	6.14	188.06	192.69		
657	cert	H167	002	8mm Rubber	nose	45	2.92	6.22	184.97	188.22		
652	cert	H168	002	8mm Rubber	nose	45	2.89	6.10	184.97	190.18		
671	cert	H170	002	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		
656	cert	H171	002	8mm Rubber	nose	45	2.88	6.05	192.68	198.79		
1033	cert	H172	006	8mm Rubber	nose	45	2.88	6.05	189.60	195.61		
1060	cert	H173	006	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		

Insert Certification Tests at the Nose

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
1025	cert	H174	006	8mm Rubber	nose	45	2.89	6.10	206.55	212.37		
1028	cert	H174	006	8mm Rubber	nose	45	2.90	6.14	184.97	189.52		
1075	cert	H176	006	8mm Rubber	nose	45	2.88	6.05	186.52	192.44		
1401	cert	H176	006	8mm Rubber	nose	45	2.90	6.14	197.31	202.17		
1036	cert	H177	006	8mm Rubber	nose	45	2.86	5.97	183.43	190.57		
1402	cert	H178	006	8mm Rubber	nose	45	2.89	6.10	197.31	202.86		
1065	cert	H180	006	8mm Rubber	nose	45	2.90	6.14	195.76	200.58		
1079	cert	H180	006	8mm Rubber	nose	45	2.90	6.14	206.55	211.63		
1049	cert	H182	006	8mm Rubber	nose	45	2.87	6.01	200.40	207.48		
1082	cert	H182	006	8mm Rubber	nose	45	2.87	6.01	192.68	199.49		
1414	cert	H183	006	8mm Rubber	nose	45	2.92	6.22	197.31	200.78		
1419	cert	H184	006	8mm Rubber	nose	45	2.89	6.10	211.18	217.13		
1405	cert	H185	006	8mm Rubber	nose	45	2.89	6.10	194.22	199.69		
318	cert	I150	005	8mm Rubber	nose	45	2.87	6.01	189.60	196.30		Shipped to MVTC February 89
314	cert	I151	005	8mm Rubber	nose	45	2.89	6.10	177.27	182.26	fx	
328	cert	I153	005	8mm Rubber	nose	45	2.75	5.52	180.35	194.87		Shipped to MVTC February 89
365	cert	I154	005	8mm Rubber	nose	45	2.85	5.93	189.60	197.67		
360	cert	I156	005	8mm Rubber	nose	45	2.86	5.97	189.59	196.97		Shipped to MVTC February 89
683	cert	I157	002	8mm Rubber	nose	45	2.88	6.05	189.60	195.61		
392	cert	I158	007	8mm Rubber	nose	45	2.81	5.76	181.89	192.33		Shipped to VRTC February 89
351	cert	I159	005	8mm Rubber	nose	45	2.81	5.76	180.35	190.71		
406	cert	I160	007	8mm Rubber	nose	45	2.75	5.52	183.43	198.20		
395	cert	I162	007	8mm Rubber	nose	45	2.75	5.52	178.80	193.19		
358	cert	I163	005	8mm Rubber	nose	45	2.83	5.85	186.52	195.84		Shipped to MVTC February 89
685	cert	I164	002	8mm Rubber	nose	45	2.88	6.05	178.81	184.48		
400	cert	I165	007	8mm Rubber	nose	45	2.76	5.56	DL			Shipped to MVTC February 89
692	cert	I166	002	8mm Rubber	nose	45	2.87	6.01	189.60	196.30		
661	cert	I167	002	8mm Rubber	nose	45	2.88	6.05	dl			
653	cert	I168	002	8mm Rubber	nose	45	2.89	6.10	186.52	191.77		
684	cert	I169	002	8mm Rubber	nose	45	2.90	6.14	DL			
654	cert	I171	002	8mm Rubber	nose	45	2.90	6.14	191.14	195.84		
1067	cert	I172	006	8mm Rubber	nose	45	2.86	5.97	192.68	200.18		
1016	cert	I173	006	8mm Rubber	nose	45	2.90	6.14	192.68	197.42		
1008	cert	I174	006	8mm Rubber	nose	45	2.91	6.18	189.60	193.60		
1039	cert	I175	006	8mm Rubber	nose	45	2.87	6.01	188.06	194.70		
1021	cert	I177	006	8mm Rubber	nose	45	2.90	6.14	188.06	192.69		
1052	cert	I178	006	8mm Rubber	nose	45	2.89	6.10	189.60	194.94		
1020	cert	I179	006	8mm Rubber	nose	45	2.91	6.18	189.60	193.60		
1071	cert	I180	006	8mm Rubber	nose	45	2.88	6.05	180.35	186.07		
1077	cert	I180	006	8mm Rubber	nose	45	2.89	6.10	180.35	185.43		
1050	cert	I181	006	8mm Rubber	nose	45	2.88	6.05	188.06	194.03		
1415	cert	I183	006	8mm Rubber	nose	45	2.91	6.18	194.22	198.32		
1420	cert	I184	006	8mm Rubber	nose	45	2.91	6.18	194.22	198.32		
1406	cert	I185	006	8mm Rubber	nose	45	2.92	6.22	194.22	197.64		
1411	cert	I186	006	8mm Rubber	nose	45	2.90	6.14	194.22	199.00		
397	cert	J150	007	8mm Rubber	nose	45	2.79	5.68	183.43	195.35		
364	cert	J151	005	8mm Rubber	nose	45	2.83	5.85	186.51	195.83		Shipped to VRTC February 89
311	cert	J152	005	8mm Rubber	nose	45	2.75	5.52	184.97	199.86		Shipped to MVTC January 89
689	cert	J153	002	8mm Rubber	nose	45	2.91	6.18	191.14	195.17		
316	cert	J155	005	8mm Rubber	nose	45	2.88	6.05	191.14	197.20		
691	cert	J157	002	8mm Rubber	nose	45	2.91	6.18	194.22	198.32		
390	cert	J158	007	8mm Rubber	nose	45	2.83	5.85	186.51	195.83		Shipped to MVTC February 89
686	cert	J159	002	8mm Rubber	nose	45	2.89	6.10	192.68	198.10		
405	cert	J160	007	8mm Rubber	nose	45	2.83	5.85	189.60	199.07		
348	cert	J161	005	8mm Rubber	nose	45	2.85	5.93	192.68	200.89		

Insert Certification Tests at the Nose

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
359	cert	J163	005	8mm Rubber	nose	45	2.86	5.97	188.05	195.37		Shipped to MVTC February 89
350	cert	J164	005	8mm Rubber	nose	45	2.85	5.93	192.68	200.89		Shipped to VRTC February 89
399	cert	J165	007	8mm Rubber	nose	45	2.73	5.44	184.97	201.32		Shipped to MVTC February 89
660	cert	J167	002	8mm Rubber	nose	45	2.89	6.10	197.30	202.85		
649	cert	J168	002	8mm Rubber	nose	45	2.88	6.05	184.97	190.84		
665	cert	J169	002	8mm Rubber	nose	45	2.89	6.10	194.22	199.69		
670	cert	J170	002	8mm Rubber	nose	45	2.88	6.05	dl			
1014	cert	J172	006	8mm Rubber	nose	45	2.86	5.97	191.14	198.58		
1015	cert	J172	006	8mm Rubber	nose	45	2.88	6.05	189.60	195.61		
1023	cert	J174	006	8mm Rubber	nose	45	2.90	6.14	172.64	176.89		
1029	cert	J174	006	8mm Rubber	nose	45	2.89	6.10	189.60	194.94		
1058	cert	J175	006	8mm Rubber	nose	45	2.89	6.10	197.31	202.86		
1061	cert	J175	006	8mm Rubber	nose	45	2.91	6.18	191.14	195.17		
1073	cert	J176	006	8mm Rubber	nose	45	2.87	6.01	184.97	191.50		
1076	cert	J176	006	8mm Rubber	nose	45	2.86	5.97	183.43	190.57		
1017	cert	J178	006	8mm Rubber	nose	45	2.88	6.05	194.22	200.38		
1009	cert	J179	006	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		
1018	cert	J180	006	8mm Rubber	nose	45	2.89	6.10	195.76	201.27		
1085	cert	J180	006	8mm Rubber	nose	45	2.87	6.01	195.76	202.67		
1055	cert	J181	006	8mm Rubber	nose	45	2.89	6.10	191.14	196.52		
1040	cert	J182	006	8mm Rubber	nose	45	2.88	6.05	183.43	189.25		
1083	cert	J182	006	8mm Rubber	nose	45	2.89	6.10	192.68	198.10		
1416	cert	J183	006	8mm Rubber	nose	45	2.91	6.18	203.57	207.86		
1421	cert	J184	006	8mm Rubber	nose	45	2.89	6.10	197.31	202.86		
1407	cert	J185	006	8mm Rubber	nose	45	2.90	6.14	194.22	199.00		
1412	cert	J186	006	8mm Rubber	nose	45	2.91	6.18	201.93	206.19		

Insert Certification Tests at the Zygoma

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
409	cert	E150	005	8mm Rubber	zygoma	66	3.46	8.74	240.47	250.10		
367	cert	E155	005	8mm Rubber	zygoma	66	3.46	8.74	232.76	242.08		
415	cert	E161	007	8mm Rubber	zygoma	66	3.47	8.79	238.93	247.78		
380	cert	E162	005	8mm Rubber	zygoma	66	3.41	8.49	240.47	253.76		
377	cert	E165	005	8mm Rubber	zygoma	66	3.47	8.79	DL			
421	cert	E165	007	8mm Rubber	zygoma	66	3.33	8.09	232.76	251.53		
411	cert	F156	005	8mm Rubber	zygoma	66	3.29	7.90	231.22	252.90		
416	cert	F161	007	8mm Rubber	zygoma	66	3.43	8.59	238.93	250.67		
423	cert	F162	007	8mm Rubber	zygoma	66	3.43	8.59	223.51	234.49		
376	cert	F163	005	8mm Rubber	zygoma	66	3.33	8.09	235.84	254.86		
431	cert	G154	007	8mm Rubber	zygoma	66	3.47	8.79	245.09	254.17		
408	cert	G156	005	8mm Rubber	zygoma	66	3.47	8.79	242.00	250.96		
430	cert	G158	007	8mm Rubber	zygoma	66	3.40	8.44	235.84	249.61		
412	cert	G160	007	8mm Rubber	zygoma	66	3.48	8.84	238.93	247.07		

Insert Certification Tests at the Zygoma

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
378	cert	G161	005	8mm Rubber	zygoma	66	3.39	8.39	DL			
426	cert	G162	007	8mm Rubber	zygoma	66	3.47	8.79	232.76	241.38		
375	cert	G163	005	8mm Rubber	zygoma	66	3.44	8.64	217.35	227.36		
417	cert	G164	007	8mm Rubber	zygoma	66	3.46	8.74	234.30	243.68		
370	cert	H151	005	8mm Rubber	zygoma	66	3.42	8.54	235.84	248.15		
428	cert	H158	007	8mm Rubber	zygoma	66	3.42	8.54	238.93	251.40		
383	cert	H159	005	8mm Rubber	zygoma	66	3.30	7.95	DL			
379	cert	H161	005	8mm Rubber	zygoma	66	3.45	8.69	237.38	247.60		
425	cert	H162	007	8mm Rubber	zygoma	66	3.46	8.74	225.05	234.06		
374	cert	H163	005	8mm Rubber	zygoma	66	3.43	8.59	232.76	244.19		
385	cert	H164	005	8mm Rubber	zygoma	66	3.43	8.59	228.14	239.35		
418	cert	H165	007	8mm Rubber	zygoma	66	3.56	9.25	237.38	239.95		
410	cert	I153	005	8mm Rubber	zygoma	66	3.46	8.74	235.84	245.28		
368	cert	I154	005	8mm Rubber	zygoma	66	3.37	8.29	229.68	245.25		
371	cert	I156	005	8mm Rubber	zygoma	66	3.43	8.59	242.00	253.89		
427	cert	I158	007	8mm Rubber	zygoma	66	3.46	8.74	240.47	250.10		
381	cert	I159	005	8mm Rubber	zygoma	66	3.46	8.74	235.84	245.28		Shipped to VRTC February 89
413	cert	I160	007	8mm Rubber	zygoma	66	3.46	8.74	226.59	235.66		
424	cert	I162	007	8mm Rubber	zygoma	66	3.41	8.49	DL			
373	cert	I163	005	8mm Rubber	zygoma	66	3.43	8.59	238.93	250.67		
419	cert	I165	007	8mm Rubber	zygoma	66	3.29	7.90	234.30	256.27		
422	cert	J150	007	8mm Rubber	zygoma	66	3.36	8.24	232.76	249.28		
369	cert	J151	005	8mm Rubber	zygoma	66	3.32	8.05	235.85	255.63		
429	cert	J158	007	8mm Rubber	zygoma	66	3.35	8.19	234.30	251.68		
414	cert	J160	007	8mm Rubber	zygoma	66	3.40	8.44	237.38	251.24		
384	cert	J161	005	8mm Rubber	zygoma	66	3.44	8.64	245.09	256.38		
372	cert	J163	005	8mm Rubber	zygoma	66	3.46	8.74	231.22	240.48		
382	cert	J164	005	8mm Rubber	zygoma	66	3.39	8.39	235.84	250.35		
420	cert	J165	007	8mm Rubber	zygoma	66	3.44	8.64	237.38	248.32		
343	cert	E152	005	8mm Rubber	zygoma	66	3.46	8.71				
340	cert	E153	005	8mm Rubber	zygoma	66	3.42	8.54	242.00	254.63		
738	cert	E159	002	8mm Rubber	zygoma	66	3.49	8.89	246.63	254.30		
723	cert	E160	002	8mm Rubber	zygoma	66	3.49	8.89	254.34	262.25		
751	cert	E167	002	8mm Rubber	zygoma	66	3.52	9.04	254.34	260.01	fx	
748	cert	E169	002	8mm Rubber	zygoma	66	3.49	8.89	251.26	259.07		
743	cert	E170	002	8mm Rubber	zygoma	66	3.49	8.89	282.09	290.86		
737	cert	E171	002	8mm Rubber	zygoma	66	3.50	8.94	254.34	261.50		
1251	cert	E173	006	8mm Rubber	zygoma	66	3.49	8.89	233.55	240.81		
1260	cert	E174	006	8mm Rubber	zygoma	66	3.50	8.94	247.38	254.34		
1261	cert	E175	006	8mm Rubber	zygoma	66	3.51	8.99	244.30	250.46		
1237	cert	E176	006	8mm Rubber	zygoma	66	3.54	9.15	238.16	242.10		
1270	cert	E177	006	8mm Rubber	zygoma	66	3.52	9.04	241.23	246.61		
1259	cert	E179	006	8mm Rubber	zygoma	66	3.50	8.94	258.14	265.40		
1229	cert	E180	006	8mm Rubber	zygoma	66	3.47	8.79	238.16	246.98		
1264	cert	E181	006	8mm Rubber	zygoma	66	3.49	8.89	250.45	258.24		
1269	cert	E182	006	8mm Rubber	zygoma	66	3.50	8.94	242.77	249.60		
1445	cert	E183	006	8mm Rubber	zygoma	66	3.51	8.99	249.72	256.02		
1426	cert	E184	006	8mm Rubber	zygoma	66	3.52	9.04	277.46	283.65		
1440	cert	E185	006	8mm Rubber	zygoma	66	3.50	8.94	260.51	267.84		
1435	cert	E186	006	8mm Rubber	zygoma	66	3.49	8.89	246.63	254.30		
336	cert	F150	005	8mm Rubber	zygoma	66	3.47	8.79	209.64	217.40	fx	
733	cert	F153	002	8mm Rubber	zygoma	66	3.51	8.99	271.30	278.14		
334	cert	F155	005	8mm Rubber	zygoma	66	3.46	8.74	197.30	205.20	fx	
726	cert	F158	002	8mm Rubber	zygoma	66	3.51	8.99	252.80	259.17		
744	cert	F159	002	8mm Rubber	zygoma	66	3.51	8.99	260.51	267.08		

Insert Certification Tests at the Zygoma

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
724	cert	F160	002	8mm Rubber	zygoma	66	3.53	9.10	254.34	259.28		
730	cert	F166	002	8mm Rubber	zygoma	66	3.52	9.04	255.88	261.59		
759	cert	F168	002	8mm Rubber	zygoma	66	3.49	8.89	254.34	262.25		
747	cert	F169	002	8mm Rubber	zygoma	66	3.51	8.99	258.96	265.49		
742	cert	F170	002	8mm Rubber	zygoma	66	3.52	9.04	260.50	266.31		
736	cert	F171	002	8mm Rubber	zygoma	66	3.50	8.94	282.09	290.03		
1252	cert	F172	006	8mm Rubber	zygoma	66	3.53	9.10	238.16	242.78		
1248	cert	F174	006	8mm Rubber	zygoma	66	3.52	9.04	239.69	245.04		
1265	cert	F175	006	8mm Rubber	zygoma	66	3.52	9.04	245.84	251.32		
1246	cert	F176	006	8mm Rubber	zygoma	66	3.48	8.84	236.62	244.68		
1238	cert	F177	006	8mm Rubber	zygoma	66	3.51	8.99	238.16	244.16		
1228	cert	F180	006	8mm Rubber	zygoma	66	3.51	8.99	255.06	261.49		
1224	cert	F181	006	8mm Rubber	zygoma	66	3.53	9.10	239.69	244.34		
1233	cert	F182	006	8mm Rubber	zygoma	66	3.53	9.10	239.69	244.34		
1444	cert	F183	006	3mm Rubber	zygoma	66	3.55	9.17	282.09	286.35		
1443	cert	F184	006	8mm Rubber	zygoma	66	3.54	9.15	255.88	260.11		
1439	cert	F185	006	8mm Rubber	zygoma	66	3.55	9.20	269.75	273.44		
1434	cert	F186	006	8mm Rubber	zygoma	66	3.51	8.99	257.42	263.91		
333	cert	G151	005	8mm Rubber	zygoma	66	3.46	8.74	237.38	246.88		
332	cert	G152	005	8mm Rubber	zygoma	66	3.45	8.69	234.30	244.39		
729	cert	G157	002	8mm Rubber	zygoma	66	3.51	8.99	257.42	263.91		
752	cert	G167	002	8mm Rubber	zygoma	66	3.51	8.99	218.88	224.40	fx	
746	cert	G169	002	8mm Rubber	zygoma	66	3.49	8.89	251.26	259.07		
741	cert	G170	002	8mm Rubber	zygoma	66	3.49	8.89	254.34	262.25		
755	cert	G171	002	8mm Rubber	zygoma	66	3.52	9.04	257.42	263.16		
1230	cert	G173	006	8mm Rubber	zygoma	66	3.51	8.99	245.84	252.04		
1226	cert	G175	006	8mm Rubber	zygoma	66	3.50	8.94	255.06	262.24		
1250	cert	G176	006	8mm Rubber	zygoma	66	3.44	8.64	244.30	255.56		
1255	cert	G177	006	8mm Rubber	zygoma	66	3.50	8.94	245.84	252.76		
1222	cert	G178	006	8mm Rubber	zygoma	66	3.50	8.94	219.72	225.90		
1257	cert	G179	006	8mm Rubber	zygoma	66	3.53	9.10	242.77	247.48		
1268	cert	G182	006	8mm Rubber	zygoma	66	3.52	9.04	238.16	243.47		
1430	cert	G183	006	8mm Rubber	zygoma	66	3.55	9.20	257.42	260.94		
1425	cert	G184	006	8mm Rubber	zygoma	66	3.53	9.10	240.47	245.14		
1442	cert	G185	006	8mm Rubber	zygoma	66	3.52	9.04	260.51	266.32		
1433	cert	G186	006	8mm Rubber	zygoma	66	3.48	8.84	243.55	251.84		
338	cert	H150	005	8mm Rubber	zygoma	66	3.44	8.64	240.46	251.54		
339	cert	H152	005	8mm Rubber	zygoma	66	3.43	8.59	238.92	250.66		
341	cert	H153	005	8mm Rubber	zygoma	66	3.44	8.64	243.56	254.78		
342	cert	H155	005	8mm Rubber	zygoma	66	3.44	8.64				
728	cert	H157	002	8mm Rubber	zygoma	66	3.51	8.99	262.05	268.66		
722	cert	H166	002	8mm Rubber	zygoma	66	3.52	9.04	255.88	261.59		
753	cert	H167	002	8mm Rubber	zygoma	66	3.48	8.84	257.42	266.19		
758	cert	H168	002	8mm Rubber	zygoma	66	3.50	8.94	237.38	244.06		
739	cert	H170	002	8mm Rubber	zygoma	66	3.52	9.04	240.46	245.82		
754	cert	H171	002	8mm Rubber	zygoma	66	3.51	8.99	DL			
1253	cert	H172	006	8mm Rubber	zygoma	66	3.50	8.94	241.23	248.02		
1266	cert	H173	006	8mm Rubber	zygoma	66	3.49	8.89	245.84	253.48		
1263	cert	H174	006	8mm Rubber	zygoma	66	3.51	8.99	244.30	250.46		
1262	cert	H176	006	8mm Rubber	zygoma	66	3.47	8.79	239.69	248.57		
1254	cert	H177	006	8mm Rubber	zygoma	66	3.46	8.74	242.77	252.49		
1429	cert	H183	006	8mm Rubber	zygoma	66	3.54	9.15	258.96	263.24		
1424	cert	H184	006	8mm Rubber	zygoma	66	3.52	9.04	260.51	266.32		
1438	cert	H185	006	8mm Rubber	zygoma	66	3.50	8.94	252.80	259.91		
1441	cert	H186	006	8mm Rubber	zygoma	66	3.51	8.99	254.34	260.75		

Insert Certification Tests at the Zygoma

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
337	cert	I150	005	8mm Rubber	zygoma	66	3.48	8.84	237.38	245.46		
735	cert	I157	002	8mm Rubber	zygoma	66	3.49	8.89	249.72	257.48		
731	cert	I166	002	8mm Rubber	zygoma	66	3.52	9.04	260.05	265.85		
749	cert	I167	002	8mm Rubber	zygoma	66	3.51	8.99	254.34	260.75		
757	cert	I168	002	8mm Rubber	zygoma	66	3.50	8.94	252.79	259.90		
734	cert	I169	002	8mm Rubber	zygoma	66	3.49	8.89	258.96	267.01		
756	cert	I171	002	8mm Rubber	zygoma	66	3.51	8.99	255.88	262.33		
1271	cert	I172	006	8mm Rubber	zygoma	66	3.49	8.89	241.23	248.73		
1235	cert	I173	006	8mm Rubber	zygoma	66	3.51	8.99	245.84	252.04		
1232	cert	I174	006	8mm Rubber	zygoma	66	3.53	9.10	261.21	266.28		
1256	cert	I175	006	8mm Rubber	zygoma	66	3.51	8.99	251.99	258.34		
1241	cert	I177	006	8mm Rubber	zygoma	66	3.52	9.04	235.08	240.32		
1225	cert	I178	006	8mm Rubber	zygoma	66	3.53	9.10	247.38	252.18		
1242	cert	I179	006	8mm Rubber	zygoma	66	3.46	8.74	235.08	244.49		
1249	cert	I180	006	8mm Rubber	zygoma	66	3.52	9.04	244.30	249.75		
1223	cert	I181	006	8mm Rubber	zygoma	66	3.53	9.10	230.47	234.94		
1428	cert	I183	006	8mm Rubber	zygoma	66	3.51	8.99	252.80	259.17		
1423	cert	I184	006	8mm Rubber	zygoma	66	3.54	9.15	262.05	266.38		
1437	cert	I185	006	8mm Rubber	zygoma	66	3.53	9.10	255.88	260.85		
1432	cert	I186	006	8mm Rubber	zygoma	66	3.50	8.94	257.42	264.66		
331	cert	J152	005	8mm Rubber	zygoma	66	3.45	8.69	243.54	254.02		
732	cert	J153	002	8mm Rubber	zygoma	66	3.52	9.04	260.05	265.85		
335	cert	J155	005	8mm Rubber	zygoma	66	3.47	8.79	243.56	252.58		
727	cert	J157	002	8mm Rubber	zygoma	66	3.53	9.10	255.88	260.85		
725	cert	J159	002	8mm Rubber	zygoma	66	3.52	9.04	252.80	258.44		
745	cert	J159	002	8mm Rubber	zygoma	66	3.52	9.04	251.25	256.85		
750	cert	J167	002	8mm Rubber	zygoma	66	3.52	9.04	258.96	264.74		
760	cert	J168	002	8mm Rubber	zygoma	66	3.51	8.99	258.96	265.49		
740	cert	J170	002	8mm Rubber	zygoma	66	3.49	8.89	257.42	265.42		
1236	cert	J172	006	8mm Rubber	zygoma	66	3.46	8.74	247.38	257.28		
1258	cert	J174	006	8mm Rubber	zygoma	66	3.50	8.94	250.45	257.50		
1267	cert	J175	006	8mm Rubber	zygoma	66	3.50	8.94	244.30	251.18		
1244	cert	J176	006	8mm Rubber	zygoma	66	3.50	8.94	250.45	257.50		
1243	cert	J178	006	8mm Rubber	zygoma	66	3.49	8.89	235.08	242.39		
1231	cert	J179	006	8mm Rubber	zygoma	66	3.42	8.54	232.01	244.12		
1234	cert	J179	006	8mm Rubber	zygoma	66	3.52	9.04	239.69	245.04		
1239	cert	J180	006	8mm Rubber	zygoma	66	3.51	8.99	250.45	256.76		
1227	cert	J181	006	8mm Rubber	zygoma	66	3.50	8.94	258.14	265.40		
1240	cert	J182	006	8mm Rubber	zygoma	66	3.53	9.10	244.30	249.04		
1427	cert	J183	006	8mm Rubber	zygoma	66	3.51	8.99	252.80	259.17		
1422	cert	J184	006	8mm Rubber	zygoma	66	3.55	9.20	dl			
1436	cert	J185	006	8mm Rubber	zygoma	66	3.49	8.89	254.34	262.25		
1431	cert	J186	006	8mm Rubber	zygoma	66	3.52	9.04	258.96	264.74		

Insert Post Barrier Crash Certification Tests at the Nose

Test No.	Test Type	Insert #	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn(g)	Adj Accn(g)	fx	Notes
1883	pcert	G104	002	436B	nose	39	2.65	5.13	156.45	163.31	fx	
1884	pcert	G028	002	436B	nose	45	2.86	5.97	210.36	218.55	fx	
1885	pcert	F108	002	436B	nose	45	2.85	5.93	167.02	174.13	fx	
1886	pcert	F101	002	436B	nose	45	2.84	5.89	191.33	200.18	fx	
1887	pcert	I132	002	436B	nose	45	2.83	5.85	162.79	170.92	fx	
1888	pcert	E125	002	436B	nose	45	2.86	5.97	172.30	179.01	fx	
1889	pcert	I124	002	436B	nose	45	2.84	5.89	160.68	168.11	fx	
1890	pcert	E109	002	436B	nose	45	2.83	5.85	170.19	178.69	fx	
2022	pcert	I159	007	296B	nose	45	2.89	6.10	214.93	220.98	fx	
2023	pcert	I158	007	296B	nose	45	2.87	6.01	210.23	217.65	fx	
2024	pcert	J151	007	296B	nose	45	2.92	6.22	209.61	213.30	fx	

APPENDIX 'B'

Drop Frame Calibration

Test No.	Date d/m/y	Test Type	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn (g)	Adj Accn(g)	Friction Loss(%)	Notes
1	28/12/88	dfc	30	2.21	3.57	169.60	186.185	17.02	6.7mm Bushing
2	28/12/88	dfc	30	2.21	3.57	168.00	184.428	17.02	6.7mm Bushing
3	28/12/88	dfc	30	2.21	3.57	168.00	184.428	17.02	6.7mm Bushing
4	28/12/88	dfc	60	3.05	6.79	226.60	254.909	20.98	6.7mm Bushing
5	28/12/88	dfc	60	3.08	6.93	226.60	252.426	19.42	6.7mm Bushing
6	28/12/88	dfc	60	3.05	6.79	225.10	253.222	20.98	6.7mm Bushing
7	28/12/88	dfc	90	3.76	10.32	274.20	306.443	19.94	6.7mm Bushing
8	28/12/88	dfc	90	3.78	10.43	271.30	301.598	19.08	6.7mm Bushing
9	28/12/88	dfc	90	3.77	10.38	268.20	298.943	19.51	6.7mm Bushing
10	28/12/88	dfc	30	2.32	3.93	175.70	183.736	8.56	7.6mm Bushing
11	28/12/88	dfc	30	2.32	3.93	174.20	182.167	8.56	7.6mm Bushing
12	28/12/88	dfc	30	2.32	3.93	175.70	183.736	8.56	7.6mm Bushing
13	28/12/88	dfc	60	3.31	8.00	242.00	250.849	6.93	7.6mm Bushing
14	28/12/88	dfc	60	3.33	8.09	240.00	247.282	5.80	7.6mm Bushing
15	28/12/88	dfc	60	3.29	7.90	237.40	247.577	8.05	7.6mm Bushing
16	28/12/88	dfc	90	4.04	11.91	294.40	306.216	7.57	7.6mm Bushing
17	28/12/88	dfc	90	4.08	12.15	291.30	300.021	5.73	7.6mm Bushing
18	28/12/88	dfc	90	4.08	12.15	289.80	298.476	5.73	7.6mm Bushing
19	28/12/88	dfc	30	2.34	4.00	171.10	177.396	6.97	8.5mm Bushing
20	28/12/88	dfc	30	2.35	4.03	171.10	176.641	6.18	8.5mm Bushing
21	28/12/88	dfc	30	2.33	3.96	172.60	179.719	7.77	8.5mm Bushing
22	28/12/88	dfc	60	3.34	8.14	237.40	243.871	5.24	8.5mm Bushing
23	28/12/88	dfc	60	3.34	8.14	235.80	242.227	5.24	8.5mm Bushing
24	28/12/88	dfc	60	3.35	8.19	235.80	241.504	4.67	8.5mm Bushing
25	28/12/88	dfc	90	4.07	12.09	288.30	297.66	6.19	8.5mm Bushing
26	28/12/88	dfc	90	4.10	12.27	286.70	293.842	4.80	8.5mm Bushing
27	28/12/88	dfc	90	4.08	12.15	291.30	300.021	5.73	8.5mm Bushing
647	9/2/89	dfc	60	3.32	8.05	238.93	246.921	6.37	7.6mm Bushing
648	9/2/89	dfc	60	3.30	7.95	238.93	248.417	7.49	7.6mm Bushing
773	15/2/89	dfc	60	3.33	8.09	248.92	256.472	5.80	7.6mm Bushing
774	15/2/89	dfc	60	3.35	8.19	242.08	247.936	4.67	7.6mm Bushing
775	15/2/89	dfc	60	3.36	8.24	242.00	247.116	4.10	7.6mm Bushing
956	8/3/89	dfc	60	3.32	8.05	246.63	254.878	6.37	7.6mm Bushing
957	8/3/89	dfc	60	3.33	8.09	242.01	249.353	5.80	7.6mm Bushing
1272	22/3/89	dfc	60	3.35	8.19	242.01	247.864	4.67	7.6mm Bushing
1273	22/3/89	dfc	60	3.32	8.05	249.72	258.072	6.37	7.6mm Bushing
1274	22/3/89	dfc	60	3.30	7.95	243.55	253.221	7.49	7.6mm Bushing
1275	22/3/89	dfc	60	3.30	7.95	243.55	253.221	7.49	7.6mm Bushing
1276	22/3/89	dfc	60	3.33	8.09	240.47	247.766	5.80	7.6mm Bushing
1446	20/4/89	dfc	60	3.32	8.05	248.17	256.47	6.37	7.6mm Bushing
1447	20/4/89	dfc	60	3.28	7.85	234.30	245.089	8.61	7.6mm Bushing
1448	20/4/89	dfc	60	3.29	7.90	235.84	245.95	8.05	7.6mm Bushing
1449	20/4/89	dfc	60	3.25	7.71	232.80	245.768	10.27	7.6mm Bushing
1450	20/4/89	dfc	60	3.30	7.95	235.84	245.205	7.49	7.6mm Bushing
1451	20/4/89	dfc	60	3.28	7.85	235.84	246.7	8.61	7.6mm Bushing
1674	3/5/89	dfc	60	3.34	8.14	239.69	246.223	5.24	7.6mm Bushing
1675	3/5/89	dfc	60	3.34	8.14	238.16	244.651	5.24	7.6mm Bushing
1676	3/5/89	dfc	60	3.32	8.05	238.16	246.125	6.37	7.6mm Bushing
1706	18/5/89	dfc	60	3.26	7.76	225.90	237.752	9.72	7.6mm Bushing
1707	18/5/89	dfc	60	3.33	8.09	232.05	239.091	5.80	7.6mm Bushing
1708	18/5/89	dfc	60	3.3	7.95	235.12	244.456	7.49	7.6mm Bushing
1939	8/6/89	dfc	60	3.26	7.76	235.73	248.097	9.72	7.6mm Bushing
1940	8/6/89	dfc	60	3.24	7.66	231.50	245.15	10.83	7.6mm Bushing
1941	8/6/89	dfc	60	3.26	7.76	231.50	243.646	9.72	7.6mm Bushing
2019	26/6/89	dfc	60	3.36	8.2414	233.89	238.835	4.10	7.6mm Bushing
2020	26/6/89	dfc	60	3.34	8.1436	233.89	240.265	5.24	7.6mm Bushing
2021	26/6/89	dfc	60	3.34	8.1436	240.21	246.757	5.24	7.6mm Bushing

APPENDIX 'C'

Destructive Quality Control Tests

Test No.	Date d/m/y	Test Type	nsert	Weight (gm)	Head Form	Skin Cover	Test Site	Test Time	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn	Adj Accn(g)
225	23/1/89	dqc	H154	77.6	003	pgr	nose	16:56:30	57	3.12	7.11	205.00	219.73
230	23/1/89	dqc	I155	78.0	003	pgr	nose	17:05:20	51	3.01	6.61	191.14	200.87
254	24/1/89	dqc	E158	78.5	005	pgr	nose	10:26:00	54	3.09	6.97	215.80	227.32
260	24/1/89	dqc	G159	78.6	005	pgr	nose	10:32:00	54	3.13	7.15	218.89	227.63
265	24/1/89	dqc	H160	76.8	005	pgr	nose	10:37:00	51	3.04	6.75	198.85	206.91
270	24/1/89	dqc	I161	77.5	005	pgr	nose	10:42:00	51	3.05	6.79	194.22	201.43
276	24/1/89	dqc	J162	77.6	005	pgr	nose	10:47:00	54	3.13	7.15	209.64	218.01
286	24/1/89	dqc	E163	76.6	007	pgr	nose	11:25:00	60	3.29	7.90	217.35	226.67
294	24/1/89	dqc	F164	78.1	007	pgr	nose	11:34:15	60	3.25	7.71	225.05	237.59
301	24/1/89	dqc	G165	78.2	007	pgr	nose	11:41:00	57	3.22	7.57	218.89	227.33
526	7/2/89	dqc	H161	77.1	001	pgr	nose	10:20:00	51	3.08	6.93	186.52	191.56
527	7/2/89	dqc	E155	78.8	001	pgr	nose	10:22:00	45	2.88	6.05	186.52	192.44
529	7/2/89	dqc	I154	77.7	001	pgr	nose	10:26:30	48	3.01	6.61	189.60	193.30
541	7/2/89	dqc	E166	78.1	002	pgr	nose	10:56:00	57	3.24	7.66	223.51	230.70
544	7/2/89	dqc	F167	76.7	002	pgr	nose	11:06:00	48	2.98	6.48	208.09	214.29
548	7/2/89	dqc	G168	74.8	002	pgr	nose	11:16:00	51	3.09	6.97	183.43	187.78
556	7/2/89	dqc	J160	78.7	004	pgr	nose	11:39:00	45	2.86	5.97	184.97	192.17
557	7/2/89	dqc	G161	78.1	004	pgr	nose	11:41:00	45	2.90	6.14	DL	
558	7/2/89	dqc	E161	78.4	004	pgr	nose	11:43:00	45	2.89	6.10	166.48	171.17
567	7/2/89	dqc	G162	78.0	006	pgr	nose	13:52:00	48	3.00	6.57	197.31	201.84
570	7/2/89	dqc	H162	77.0	006	pgr	nose	13:59:00	51	3.02	6.66	208.10	217.97
575	7/2/89	dqc	E162	78.2	006	pgr	nose	14:13:00	54	3.16	7.29	194.22	200.06
588	7/2/89	dqc	H169	76.0	007	pgr	nose	15:18:00	48	3.00	6.57	198.85	203.41
594	7/2/89	dqc	I170	75.3	007	pgr	nose	15:36:00	60	3.36	8.24	208.10	212.50
597	7/2/89	dqc	J171	79.7	007	pgr	nose	15:45:00	51	3.08	6.93	200.39	205.81
680	9/2/89	rdqc	F165	77.5	002	pgr	nose	13:33:00	60	3.34	8.14	229.68	235.94
704	9/2/89	rdqc	J166	78.7	002	pgr	nose	14:21:00	57	3.26	7.76	215.80	221.37
713	9/2/89	rdqc	G166	77.9	002	pgr	nose	14:31:00	63	3.43	8.59	234.30	240.16
960	8/3/89	dqc	G180	76.3	001	pgr	nose	9:34;30	51	3.09	6.97	212.72	217.76
963	8/3/89	dqc	I182	76.1	001	pgr	nose	9:37:00	51	3.09	6.97	208.10	213.03
966	8/3/89	dqc	H175	77.9	001	pgr	nose	9:41:00	51	3.08	6.93	200.40	205.82
969	8/3/89	dqc	G174	76.9	003	pgr	nose	9:56:00	51	3.06	6.84	214.26	221.49
976	8/3/89	dqc	E178	78.3	003	pgr	nose	10:01:00	60	3.33	8.09	245.09	252.53
983	8/3/89	dqc	F173	78.6	003	pgr	nose	10:10:00	63	3.42	8.54	255.88	263.04
984	8/3/89	dqc	H181	76.4	004	pgr	nose	10:19:00	45	2.86	5.97	181.89	188.97
987	8/3/89	dqc	I176	76.9	004	pgr	nose	10:24:00	45	2.90	6.14	184.97	189.52
992	8/3/89	dqc	F179	78.2	006	pgr	nose	10:37:00	57	3.23	7.62	214.26	221.83
996	8/3/89	dqc	E172	79.6	006	pgr	nose	10:42:00	54	3.18	7.38	221.97	227.20
1002	8/3/89	dqc	J177	80.0	006	pgr	nose	10:48:00	60	3.33	8.09	242.01	249.35
1006	8/3/89	dqc	G181	77.6	006	pgr	nose	11:51:00	54	3.15	7.24	218.89	226.18
1087	9/3/89	dqc	H180	75.0	006	pgr	nose	13:24:00	51	3.03	6.70	DL	
1720	18/5/89	dqc	H186	74.9	008	pgr	nose	NA	60	3.33	8.09	215.14	221.67
1726	18/5/89	dqc	F184	76.6	008	pgr	nose	NA	54	3.19	7.43	204.38	208.54
1985	32848	dqc	G173	78.9	002	pgr	nose	14:05:00	69	3.46	8.74	DL	
1991	32848	dqc	J153	79.5	002	pgr	nose	14:16:00	60	3.27	7.81	240.9	252.74
1998	32848	dqc	I183	76.7	002	pgr	nose	14:50:00	63	3.32	8.05	248.3	262.92
2006	32848	dqc	J181	79.3	002	pgr	nose	15:25:00	66	3.4	8.44	248.2	262.69
2013	32848	dqc	I180	74.9	002	pgr	nose	15:41:00	63	3.32	8.05	241.9	256.21
2018	32848	dqc	H157	77.8	002	pgr	nose	15:54:00	57	3.18	7.38	219.7	231.08

APPENDIX 'D'

Numbering Sequence Used in Graphs

Graph ID #	Skin Cover #
1	342-B
2	391-B
3	393-B
4	394-B
5	395-B
6	396-B
7	419-B
8	432-B
9	434-B
10	436-B
11	438-B
12	442-B
13	447-B
14	448-B
15	453-B
16	454-B
17	455-B

APPENDIX 'E'

Insert System Testing at the Nose

Test No.	Date d/m/y	Test Type	Insert #	Weight (gm)	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn	Adj Accn(g)
1281	22/3/89	isys	F175	76.6	006	434B	nose	48	3.02	6.66	208.10	211.46
1284	22/3/89	isys	G157	78.3	006	455B	nose	39	2.76	5.56	208.10	208.57
1288	22/3/89	isys	H172	77.8	006	395B	nose	45	2.86	5.97	220.43	229.01
1292	22/3/89	isys	I162	76.9	006	448B	nose	45	2.92	6.22	212.72	216.46
1296	22/3/89	isys	J178	79.2	006	342B	nose	45	2.91	6.18	217.35	221.93
1297	22/3/89	isys	F170	76.0	006	442B	nose	36	2.60	4.93	178.81	182.78
1303	22/3/89	isys	G178	77.9	006	434B	nose	48	2.98	6.48	231.22	238.11
1304	22/3/89	isys	H168	73.2	006	455B	nose	36	2.57	4.82	183.43	189.69
1309	22/3/89	isys	I177	77.8	006	395B	nose	48	2.97	6.44	228.14	235.73
1315	22/3/89	isys	J180	77.9	006	448B	nose	48	3.01	6.61	242.00	246.73
1317	22/3/89	isys	E180	76.8	006	342B	nose	39	2.71	5.36	197.31	201.40
1319	22/3/89	isys	E159	78.6	006	442B	nose	39	2.70	5.32	218.89	224.26
1322	22/3/89	isys	E170	77.5	006	436B	nose	42	2.79	5.68	211.18	217.28
1326	22/3/89	isys	F182	77.4	006	391B	nose	45	2.90	6.14	212.72	217.95
1330	22/3/89	isys	G179	78.2	006	447B	nose	45	2.92	6.22	243.55	247.83
1335	22/3/89	isys	H174	78.6	006	394B	nose	45	2.91	6.18	215.80	220.35
1340	22/3/89	isys	I173	77.6	006	438B	nose	48	2.99	6.53	231.22	237.31
1343	23/3/89	isys	J168	75.3	006	454B	nose	42	2.82	5.81	198.85	202.42
1346	23/3/89	isys	E152	77.7	006	432B	nose	42	2.79	5.68	203.47	209.35
1348	23/3/89	isys	F163	76.1	006	419B	nose	39	2.68	5.24	208.10	214.79
1350	23/3/89	isys	G176	75.9	006	453B	nose	39	2.73	5.44	194.22	196.79
1353	23/3/89	isys	H164	76.6	006	436B	nose	42	2.79	5.68	191.14	196.66
1356	23/3/89	isys	I171	77.0	006	391B	nose	42	2.80	5.72	198.85	203.86
1359	23/3/89	isys	J150	79.0	006	447B	nose	42	2.80	5.72	212.72	218.08
1366	23/3/89	isys	E176	78.1	006	394B	nose	51	3.07	6.88	215.80	222.36
1369	23/3/89	isys	G177	79.3	006	438B	nose	42	2.79	5.68	227.40	233.97
1371	23/3/89	isys	H166	76.3	006	454B	nose	39	2.71	5.36	205.88	210.15
1374	23/3/89	isys	J159	79.6	006	432B	nose	42	2.79	5.68	225.86	232.39
1378	23/3/89	isys	I172	78.0	006	419B	nose	45	2.91	6.18	241.23	246.32
1380	23/3/89	isys	F158	78.3	006	453B	nose	39	2.72	5.40	208.96	212.51
2073	29/6/89	isys	E184	77.3	007	455B	nose	48	3.01	6.61	220.29	224.59
2075	29/6/89	isys	I162	76.9	007	455B	nose	39	2.69	5.28	203.38	209.14
2078	29/6/89	isys	F161	77.5	007	419B	nose	42	2.79	5.68	217.21	223.49
2082	29/6/89	isys	E185	77.6	007	419B	nose	45	2.86	5.97	223.36	232.06

Insert System Testing at the Zygoma

Test No.	Date d/m/y	Test Type	Insert #	Weight (gm)	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn	Adj Accn(g)
1474	20/4/89	isys	J185	79.0	003	436B	zygoma	90	4.09	12.21	306.74	315.15
1480	20/4/89	isys	F186	75.9	003	436B	zygoma	84	3.94	11.33	279.00	287.47
1489	20/4/89	isys	I185	76.4	003	453B	zygoma	96	4.24	13.12	312.92	320.30
1501	20/4/89	isys	H176	77.5	003	453B	zygoma	105	4.41	14.20	292.88	301.44
1514	24/4/89	isys	F177	78.7	003	395B	zygoma	108	4.45	14.46	334.50	346.02
1529	24/4/89	isys	J186	78.2	003	395B	zygoma	123	4.77	16.61	306.75	315.91
1532	24/4/89	isys	I186	74.9	003	447B	zygoma	87	4.01	11.74	275.92	284.28
1533	24/4/89	isys	F174	76.9	003	447B	zygoma	81	3.86	10.88	266.67	275.41
1540	24/4/89	isys	F172	78.8	003	442B	zygoma	99	4.27	13.31	320.62	330.93
1545	24/4/89	isys	J174	78.7	003	442B	zygoma	93	4.14	12.51	305.21	314.91
1557	24/4/89	isys	F183	77.4	003	391B	zygoma	114	4.69	16.06	322.95	335.74
1565	24/4/89	isys	I160	76.9	003	391B	zygoma	102	4.36	13.88	314.46	322.65
1569	24/4/89	isys	J176	77.5	006	436B	zygoma	90	4.08	12.15	306.75	315.93
1573	24/3/89	isys	H185	75.9	006	436B	zygoma	90	4.08	12.15	271.30	279.42
1587	24/4/89	isys	G183	77.5	006	453B	zygoma	120	4.69	16.06	325.25	336.50
1593	25/4/89	isys	F176	75.4	006	453B	zygoma	96	4.23	13.06	291.34	298.91
1609	25/4/89	isys	H173	77.7	006	395B	zygoma	126	4.87	17.21	326.79	333.64
1619	25/4/89	isys	J175	78.3	006	395B	zygoma	108	4.46	14.52	295.96	305.46
1621	25/4/89	isys	F169	77.0	006	447B	zygoma	84	3.93	11.27	282.09	291.40
1622	25/4/89	isys	I166	76.6	006	447B	zygoma	81	3.87	10.93	265.13	273.11
1628	25/4/89	isys	G186	75.9	006	442B	zygoma	96	4.24	13.12	275.92	282.42
1632	25/4/89	isys	H165	76.7	006	442B	zygoma	90	4.07	12.09	251.26	259.42
1645	25/4/89	isys	I181	76.1	006	391B	zygoma	117	4.65	15.78	322.16	331.94
1655	25/4/89	isys	F159	78.0	006	391B	zygoma	108	4.59	15.38	274.38	275.17
1784	24/5/89	isys	F153	78.3	006	454B	zygoma	87	3.94	11.33	291.27	305.43
1788	24/5/89	isys	F160	77.7	006	454B	zygoma	90	4.03	11.86	274.36	286.08
1797	24/5/89	isys	E171	78.3	006	455B	zygoma	84	3.87	10.93	285.96	299.99
1808	25/5/89	isys	E175	79.2	006	455B	zygoma	111	4.49	14.72	346.72	360.37
2038	29/6/89	isys	I184	75.9	007	438B	zygoma	96	4.25	13.19	341.69	348.92
2046	29/6/89	isys	I178	76.3	007	438B	zygoma	102	4.38	14.00	329.39	336.42
2054	29/6/89	isys	H184	75.7	007	448B	zygoma	102	4.46	14.52	367.81	368.93
2064	29/6/89	isys	I169	76.2	007	419B	zygoma	108	4.5	14.78	347.84	355.82
2068	29/6/89	isys	I169	76.1	007	419B	zygoma	90	4.1	12.27	323.25	331.30

Insert System Testing at the Maxilla,Right Zygoma,Right Maxilla

Test No.	Date d/m/y	Test Type	Insert #	Weight (gm)	Head Form	Skin Cover	Test Site	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn	Adj Accn(g)
1811	25/5/89	isys	E169	77.6	006	447B	maxilla	42	2.75	5.52	187.10	195.31
1814	25/5/89	isys	F180	76.3	006	447B	maxilla	42	2.75	5.52	200.85	209.66
1817	25/5/89	isys	F168	74.0	006	436B	maxilla	42	2.74	5.48	197.67	207.09
1821	25/5/89	isys	G170	77.0	006	436B	maxilla	45	2.82	5.81	164.90	173.75
2084	30/6/89	isys	G175	76.6	007	447B	maxilla	39	2.71	5.36	194.16	198.19
2088	30/6/89	isys	H171	77.0	007	447B	maxilla	45	2.86	5.97	214.14	222.48
2092	30/6/89	isys	J170	76.8	007	436B	maxilla	45	2.86	5.97	214.14	222.48
2094	30/6/89	isys	H170	74.8	007	436B	maxilla	39	2.66	5.17	184.94	192.32
1825	25/5/89	isys	G169	77.7	006	447B	Rzygoma	90	4.03	11.86	265.33	276.66
1834	29/5/89	isys	H155	78.0	006	436B	Rzygoma	93	4.09	12.21	265.33	277.11
1840	29/5/89	isys	H153	77.5	006	436B	Rzygoma	99	4.17	12.69	287.53	303.89
1845	29/5/89	isys	E177	79.4	006	436B	Rzygoma	99	4.23	13.06	310.78	323.80
1851	29/5/89	isys	E181	78.0	006	436B	Rzygoma	102	4.24	13.12	305.49	322.32
1863	30/5/89	isys	J184	79.1	006	436B	Rmaxilla	57	3.19	7.43	226.22	237.15
1869	30/5/89	isys	F160	77.7	006	436B	Rmaxilla	51	3.03	6.70	189.22	197.54
1876	30/5/89	isys	E183	78.1	006	436B	Rmaxilla	54	3.17	7.34	229.39	235.54
1882	30/5/89	isys	F162	77.9	006	436B	Rmaxilla	51	3.09	6.97	193.45	198.04
2101	30/6/89	isys	I179	77.1	007	455B	Rmaxilla	54	3.17	7.34	231.04	237.23
2106	30/6/89	isys	G163	76.6	007	455B	Rmaxilla	48	2.97	6.44	189.55	195.86

APPENDIX 'F'

Subsystem Component Tests

Test No.	Date d/m/y	Test Type	Head Form	Skin Cover	Test Site	Test Time	DH (cm)	Velocity (m/s)	Energy (J)	Peak Accn.	Adj Accn(g)
516	7/2/89	mnst	001	pgr	nose	9:59:00	30	2.36	4.07	144.89	148.95
517	7/2/89	mnst	001	pgr	nose	10:00:00	30	2.34	4.00	141.81	147.03
518	7/2/89	mnst	001	pgr	nose	10:01:00	30	2.33	3.96	135.65	141.25
519	7/2/89	mnst	001	pgr	nose	10:03:00	30	2.36	4.07	138.73	142.62
520	7/2/89	mnst	001	pgr	nose	10:04:00	51			DL	
521	7/2/89	mnst	001	pgr	nose	10:05:00	51	3.09	6.97	231.22	236.70
522	7/2/89	mnst	001	pgr	nose	10:06:00	51	3.08	6.93	229.68	235.89
523	7/2/89	mnst	001	pgr	nose	10:08:00	51	3.09	6.97	229.68	235.13
530	7/2/89	mnst	002	pgr	nose	10:36:00	30	2.33	3.96	138.70	144.42
531	7/2/89	mnst	002	pgr	nose	10:37:00	30	2.32	3.93	137.19	143.46
532	7/2/89	mnst	002	pgr	nose	10:38:00	30	2.33	3.96	132.57	138.04
533	7/2/89	mnst	002	pgr	nose	10:40:00	30	2.32	3.93	132.57	138.63
534	7/2/89	mnst	002	pgr	nose	10:41:00	51	3.08	6.93	218.89	224.81
535	7/2/89	mnst	002	pgr	nose	10:43:00	51	3.06	6.84	223.51	231.05
536	7/2/89	mnst	002	pgr	nose	10:44:00	51	3.05	6.79	223.51	231.81
549	7/2/89	mnst	004	pgr	nose	11:28:00	30	2.34	4.00	137.19	142.24
550	7/2/89	mnst	004	pgr	nose	11:29:00	30	2.33	3.96	140.27	146.06
551	7/2/89	mnst	004	pgr	nose	11:30:00	30	2.35	4.03	141.81	146.40
552	7/2/89	mnst	004	pgr	nose	11:31:00	30	2.36	4.07	152.60	156.87
553	7/2/89	mnst	004	pgr	nose	11:33:00	51	3.08	6.93	231.22	237.47
554	7/2/89	mnst	004	pgr	nose	11:35:00	51	3.18	7.38	235.84	234.60
555	7/2/89	mnst	004	pgr	nose	11:37:00	51	3.09	6.97	231.22	236.70
559	7/2/89	mnst	006	pgr	nose	13:35:00	30	2.32	3.93	137.19	143.46
560	7/2/89	mnst	006	pgr	nose	13:37:00	30	2.29	3.83	132.57	140.45
561	7/2/89	mnst	006	pgr	nose	13:39:00	30	2.38	4.14	140.27	142.99
562	7/2/89	mnst	006	pgr	nose	13:41:00	30	2.33	3.96	137.19	142.85
563	7/2/89	mnst	006	pgr	nose	13:43:00	51	3.06	6.84	226.59	234.24
564	7/2/89	mnst	006	pgr	nose	13:45:00	51	3.06	6.84	223.51	231.05
565	7/2/89	mnst	006	pgr	nose	13:47:00	51	3.02	6.66	221.97	232.50
580	7/2/89	mnst	007	pgr	nose	15:00:00	30	2.35	4.03	135.65	140.04
581	7/2/89	mnst	007	pgr	nose	15:02:00	30	DL		137.19	
582	7/2/89	mnst	007	pgr	nose	15:05:00	30	2.36	4.07	137.19	141.03
583	7/2/89	mnst	007	pgr	nose	15:07:00	30	2.34	4.00	135.65	140.64
584	7/2/89	mnst	007	pgr	nose	15:09:00	51	3.09	6.97	226.59	231.96
585	7/2/89	mnst	007	pgr	nose	15:11:00	51	3.09	6.97	232.76	238.28
586	7/2/89	mnst	007	pgr	nose	15:13:00	51	3.10	7.02	228.14	232.80
1452	20/4/89	mnst	003	pgr	zygoma	12:00:00	69	3.56	9.25	267.36	276.33
1453	20/4/89	mnst	003	pgr	zygoma	12:10:00	69	3.56	9.25	270.42	279.49
1454	20/4/89	mnst	003	pgr	zygoma	12:15:00	69	3.54	9.15	262.75	273.09
1455	20/4/89	mnst	003	pgr	zygoma	12:17:00	69	3.58	9.36	264.28	271.62
1456	20/4/89	mnst	003	pgr	zygoma	12:18:00	69	3.56	9.25	265.82	274.73
1457	20/4/89	mnst	003	pgr	zygoma	12:19:00	69	3.56	9.25	265.82	274.73
1458	20/4/89	mnst	003	pgr	zygoma	12:20:00	69	3.53	9.10	279.65	291.48
1459	20/4/89	mnst	003	pgr	zygoma	12:22:00	69	3.56	9.25	264.28	273.14
1460	20/4/89	mnst	003	pgr	zygoma	12:26:00	69	3.56	9.25	259.67	268.38
1461	20/4/89	mnst	003	pgr	zygoma	12:29:00	69	3.57	9.30	256.60	264.46

APPENDIX 'G'

REVISION RECORD			
DATE	LET	CHANGES	BY

HEAD IMPACT RESPONSE SPECIFICATIONS

1. OBJECTIVE

(1.1) THE OBJECTIVE OF THESE SPECIFICATIONS IS TO CONTROL THE HYBRID III HEAD RESPONSE TO FRONTAL IMPACTS WITH HARD SURFACES.

2. TEST MATERIAL

(2.1) HEAD ASSEMBLY (P/N 78051-61) WITH NECK TRANSDUCER STRUCTURAL REPLACEMENT (P/N 78051-383).

3. INSTRUMENTATION

(3.1) A DATA ACQUISITION SYSTEM WHICH CONFORMS TO THE SPECIFICATIONS OF SAE RECOMMENDED PRACTICE J211A (REVISED DEC 1971) FOR CHANNEL CLASS 1000.

4. TEST PROCEDURE

(4.1) TEST SETUP AS PER SPECIFICATIONS SHOWN IN FIGURE 1.

(4.2) ALLOW THE TEST MATERIAL TO SOAK IN A TEST ENVIRONMENT OF ANY TEMPERATURE BETWEEN 19° C (66° F) TO 25° C (78° F) AND AT A RELATIVE HUMIDITY FROM 10% TO 70% FOR A PERIOD OF AT LEAST FOUR HOURS PRIOR TO THE TEST.

(4.3) CLEAN SKIN SURFACE AND SURFACE OF THE IMPACT PLATE WITH 1,1,1 TRICHLOROETHANE OR EQUIVALENT.

(4.4) PERFORM THREE TESTS ACCORDING TO THE PROCEDURE IN SECTION 4. ALLOW A TIME PERIOD OF AT LEAST TWO HOURS BETWEEN SUCCESSIVE TESTS.

(4.5) THE HEAD RESPONSE SHALL MEET THE SPECIFICATIONS OF PARAGRAPH 5.

NOTE: THE HARD SURFACE IMPACT RESPONSE MAY BE ADJUSTED BY THE APPLICATION OF SILICONE GREASE (DOW CORNING 4 COMPOUND OR EQUIVALENT) BETWEEN THE SKULL (PART NO. 78051-77) AND VINYL SKIN (PART NO. 78051-228).

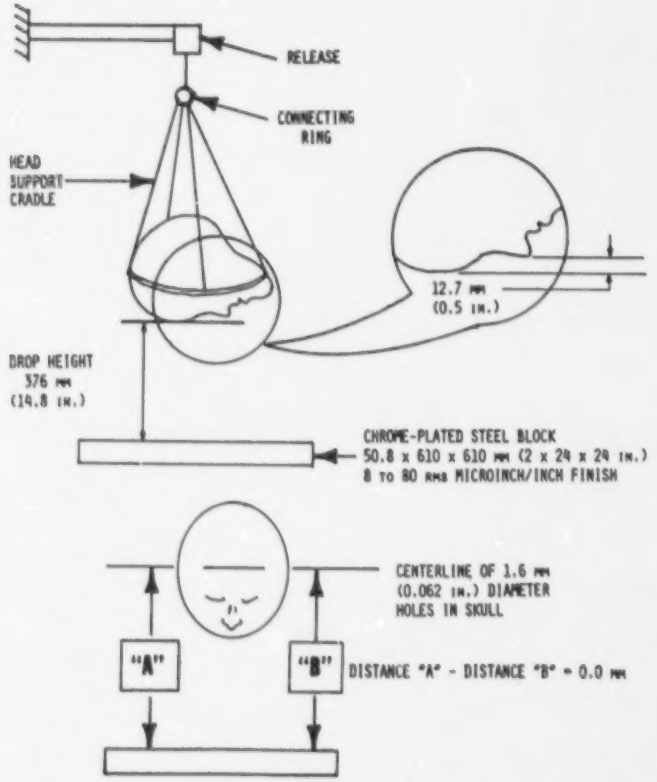
5. PERFORMANCE SPECIFICATIONS

(5.1) TIME ZERO IS DEFINED AS THE TIME OF CONTACT BETWEEN THE HEAD ASSEMBLY AND THE CHROME-PLATED STEEL BLOCK. THE LEVEL OF A DATA CHANNEL AT TIME ZERO IS DEFINED AS THE ZERO LEVEL FOR THAT CHANNEL.

(5.2) IN EACH TEST, THE MAXIMUM RESULTANT ACCELERATION AT THE CENTER OF GRAVITY OF THE HEAD (REFERENCE DRAWING NO. 78051-338, SHEET 2 OF 2) SHALL NOT BE LESS THAN 225 g's AND NOT MORE THAN 275 g's. THE ACCELERATION-TIME CURVE SHALL BE UNIMODAL TO THE EXTENT THAT OSCILLATIONS OCCURRING AFTER THE MAIN ACCELERATION PULSE ARE LESS THAN FIVE PERCENT (ZERO-TO-PEAK) OF THE MAIN PULSE. THE LATERAL ACCELERATION VECTOR SHALL NOT EXCEED 15 g's (ZERO-TO-PEAK).

FIGURE 1

TEST SET-UP FOR HEAD IMPACT RESPONSE TEST


RELEASE
CONNECTING RING
HEAD SUPPORT CRADLE
12.7 mm (0.5 in.)
DROP HEIGHT 376 mm (14.8 in.)
CHROME-PLATED STEEL BLOCK
50.8 x 610 x 610 mm (2 x 24 x 24 in.)
8 TO 80 RMS MICROINCH/INCH FINISH
CENTERLINE OF 1.6 mm (0.062 in.) DIAMETER HOLES IN SKULL
"A"
"B"
DISTANCE "A" - DISTANCE "B" = 0.0 mm

NOTE: TOLERANCE ON TEST SETUP DIMENSIONS ±1 mm (0.04 in.)

NOTE: READ CAREFULLY BEFORE STARTING; REPORT ALL ERRORS

DO NOT SCALE UNLESS OTHERWISE SPECIFIED, ALLOWABLE VARIATION ON ALL DIMENSIONS: DECIMALS: ±___ FRACTIONS: ±___ ANGLES: ±___ FINISH:	DWG. BY: R. S. STEVENS ENGR.: R. J. DOBARIO DATE: 12-10-79 PROJ. NO. 90-3830-001 MATERIAL: HEAT TREAT:	GM PROVING GROUND GENERAL MOTORS CORPORATION	TITLE: HEAD IMPACT RESPONSE SPECIFICATIONS, DYNAMIC— HYBRID III SCALE: SHEET DWG. NO. 78051-62

APPENDIX 'H'

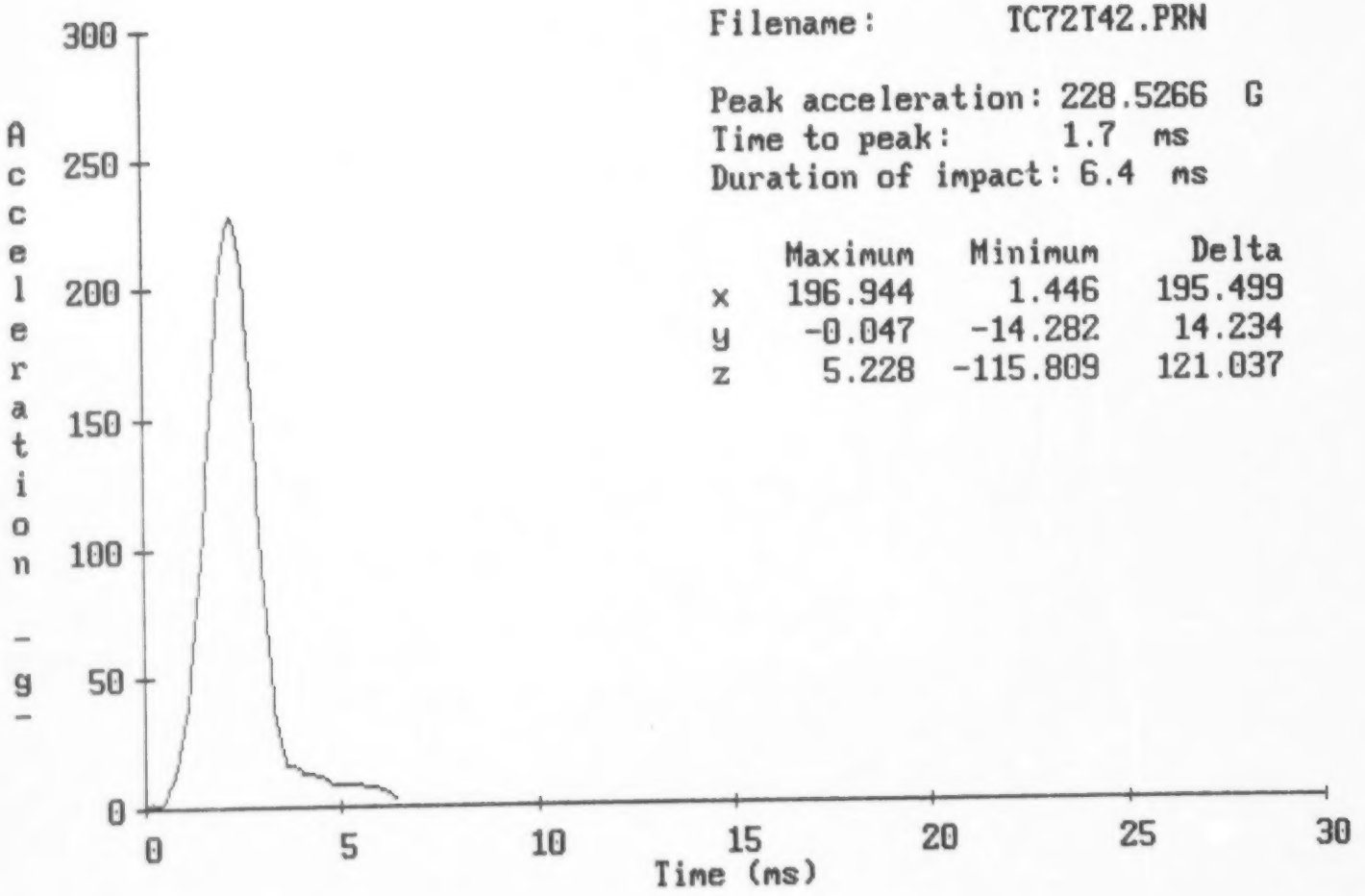
BIOKINETICS AND ASSOCIATES LTD.
HEAD DROP TEST
HYBRID IIIe

Preliminary Information:

Skull Serial No.: 002
Skin Serial No.: 438 B
Filename: TC72T42.prn

Date: August 15, 1989
Technician: T. Smith

Test Parameter	Specifications	Test Results
Temperature	18.98 - 25.6 deg.	21°
Relative Humidity	10% - 70%	49%
Peak Resultant Acc'n	225 - 275 g.	228.5 g
Peak Lateral Acc'n	15 g max.	14.3 g
Is Acc'n Curve Unimodal?	Yes	Yes



Filename: TC72T42.PRN

Peak acceleration: 228.5266 G
Time to peak: 1.7 ms
Duration of impact: 6.4 ms

	Maximum	Minimum	Delta
x	196.944	1.446	195.499
y	-0.047	-14.282	14.234
z	5.228	-115.809	121.037

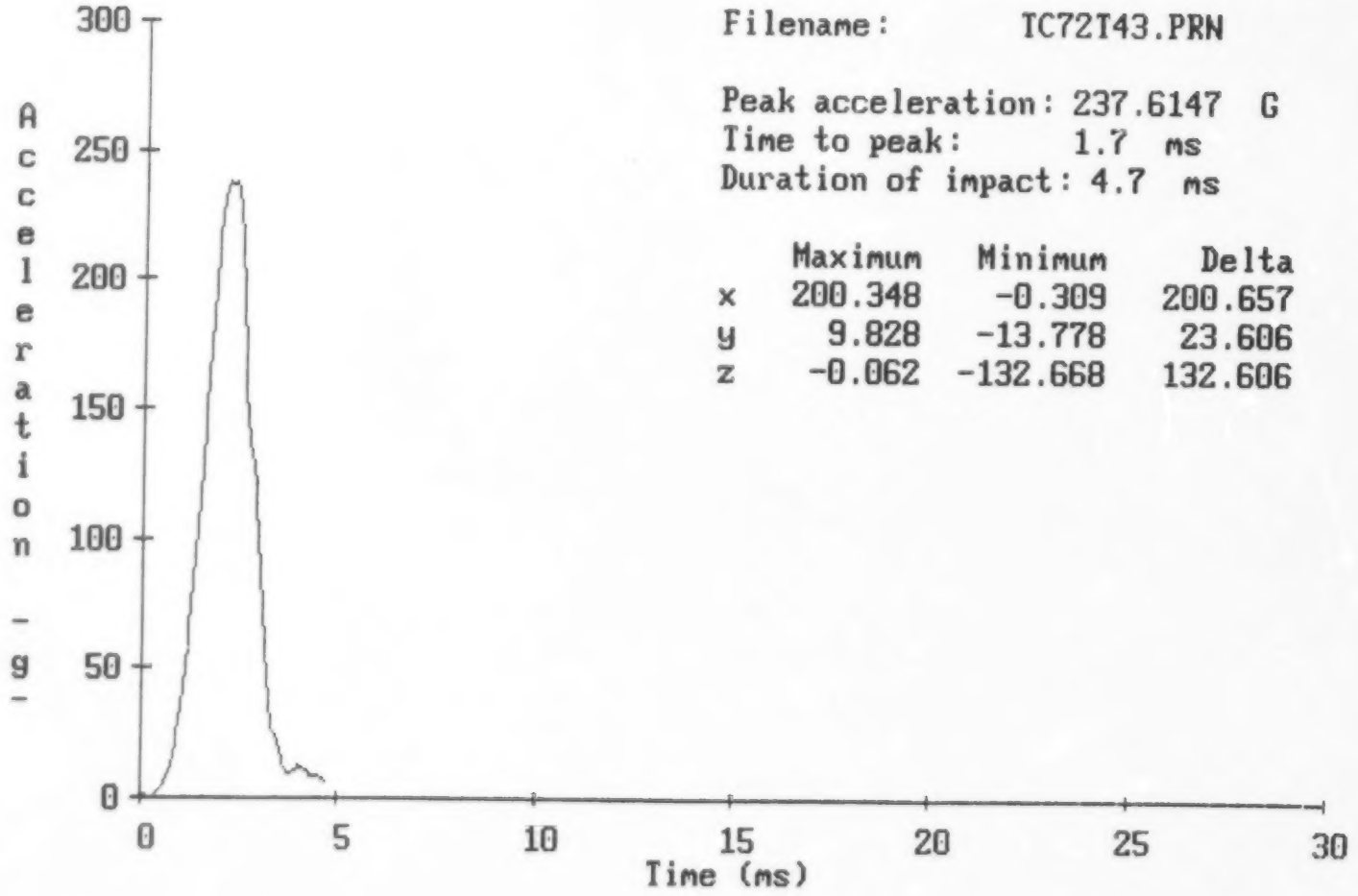
BIOKINETICS AND ASSOCIATES LTD.
HEAD DROP TEST
HYBRID IIIe

Preliminary Information:

Skull Serial No.: 002
Skin Serial No.: 448 B
Filename: TC72T43.prn

Date: August 16, 1989
Technician: T. Smith

Test Parameter	Specifications	Test Results
Temperature	18.98 - 25.6 deg.	20°
Relative Humidity	10% - 70%	52%
Peak Resultant Acc'n	225 - 275 g.	237.6
Peak Lateral Acc'n	15 g max.	13.8
Is Acc'n Curve Unimodal?	Yes	Yes



Filename: TC72T43.PRN

Peak acceleration: 237.6147 G
Time to peak: 1.7 ms
Duration of impact: 4.7 ms

	Maximum	Minimum	Delta
x	200.348	-0.309	200.657
y	9.828	-13.778	23.606
z	-0.062	-132.668	132.606

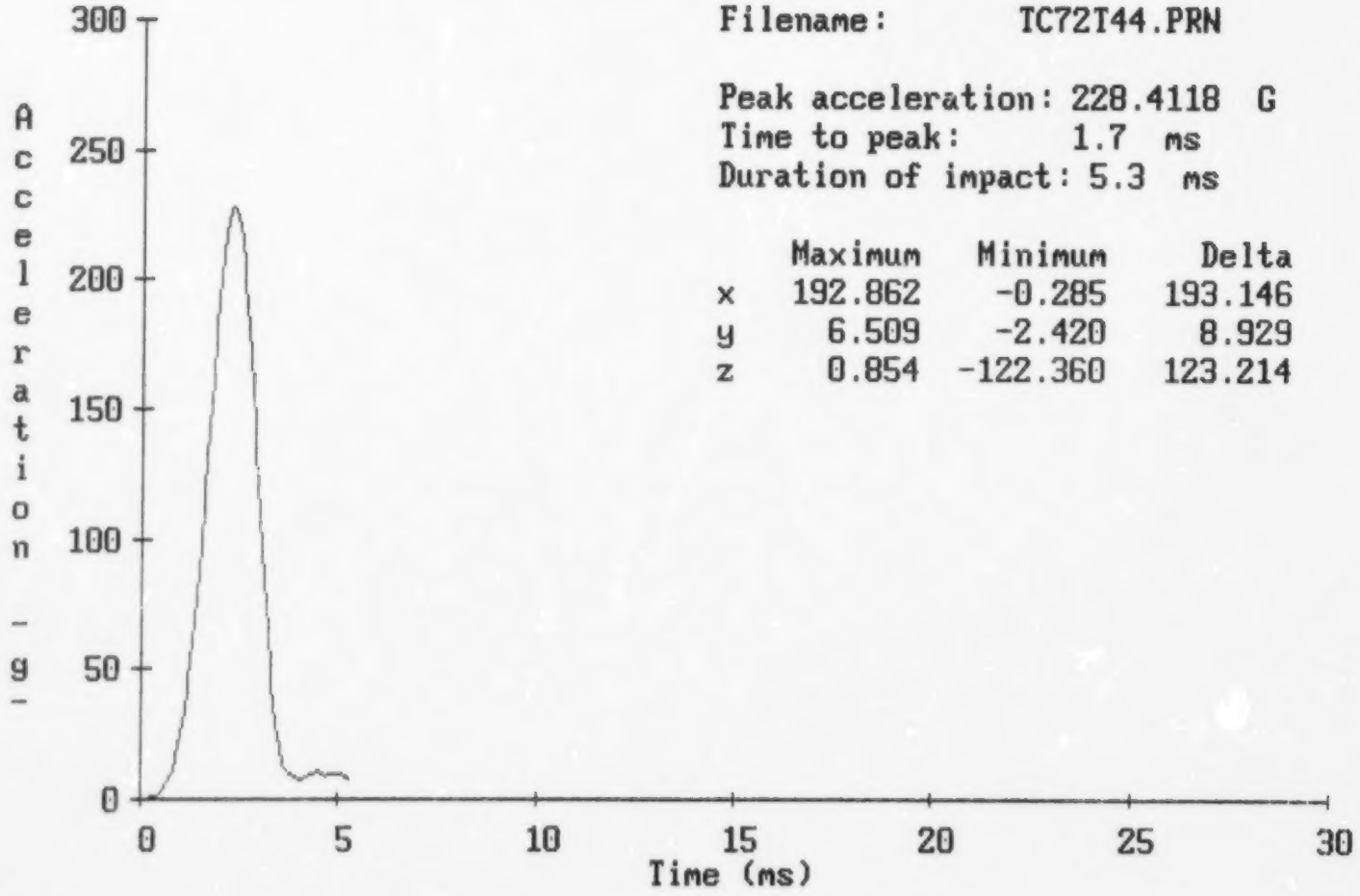
BIOKINETICS AND ASSOCIATES LTD.
HEAD DROP TEST
HYBRID IIIe

Preliminary Information:

Skull Serial No.: 003
Skin Serial No.: 442 B
Filename: TC72T44.prn

Date: August 16, 1989
Technician: T. Szabo

Test Parameter	Specifications	Test Results
Temperature	18.98 - 25.6 deg.	20°
Relative Humidity	10% - 70%	52%
Peak Resultant Acc'n	225 - 275 g.	228.4 g
Peak Lateral Acc'n	15 g max.	6.5 g
Is Acc'n Curve Unimodal?	Yes	Yes



Filename: TC72T44.PRN

Peak acceleration: 228.4118 G
Time to peak: 1.7 ms
Duration of impact: 5.3 ms

	Maximum	Minimum	Delta
x	192.862	-0.285	193.146
y	6.509	-2.420	8.929
z	0.854	-122.360	123.214

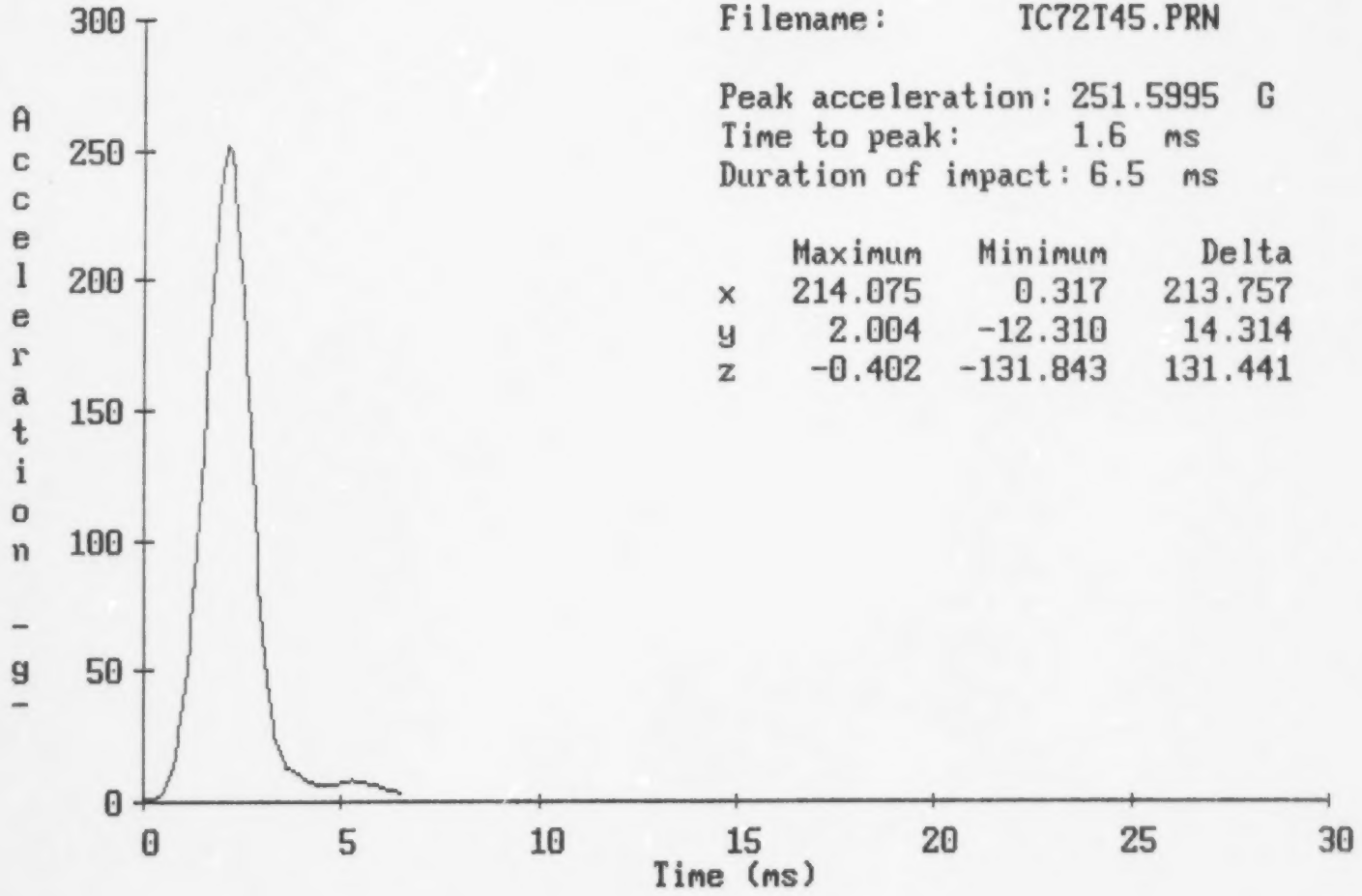
BIOKINETICS AND ASSOCIATES LTD.
HEAD DROP TEST
HYBRID IIIe

Preliminary Information:

Skull Serial No.: 003
Skin Serial No.: 447 B
Filename: TC72T45.prn

Date: August 16, 1989
Technician: T. Szabo

Test Parameter	Specifications	Test Results
Temperature	18.98 - 25.6 deg.	20°
Relative Humidity	10% - 70%	52%
Peak Resultant Acc'n	225 - 275 g.	251.6 g
Peak Lateral Acc'n	15 g max.	12.3 g
Is Acc'n Curve Unimodal?	Yes	Yes



Filename: TC72T45.PRN

Peak acceleration: 251.5995 G
Time to peak: 1.6 ms
Duration of impact: 6.5 ms

	Maximum	Minimum	Delta
x	214.075	0.317	213.757
y	2.004	-12.310	14.314
z	-0.402	-131.843	131.441

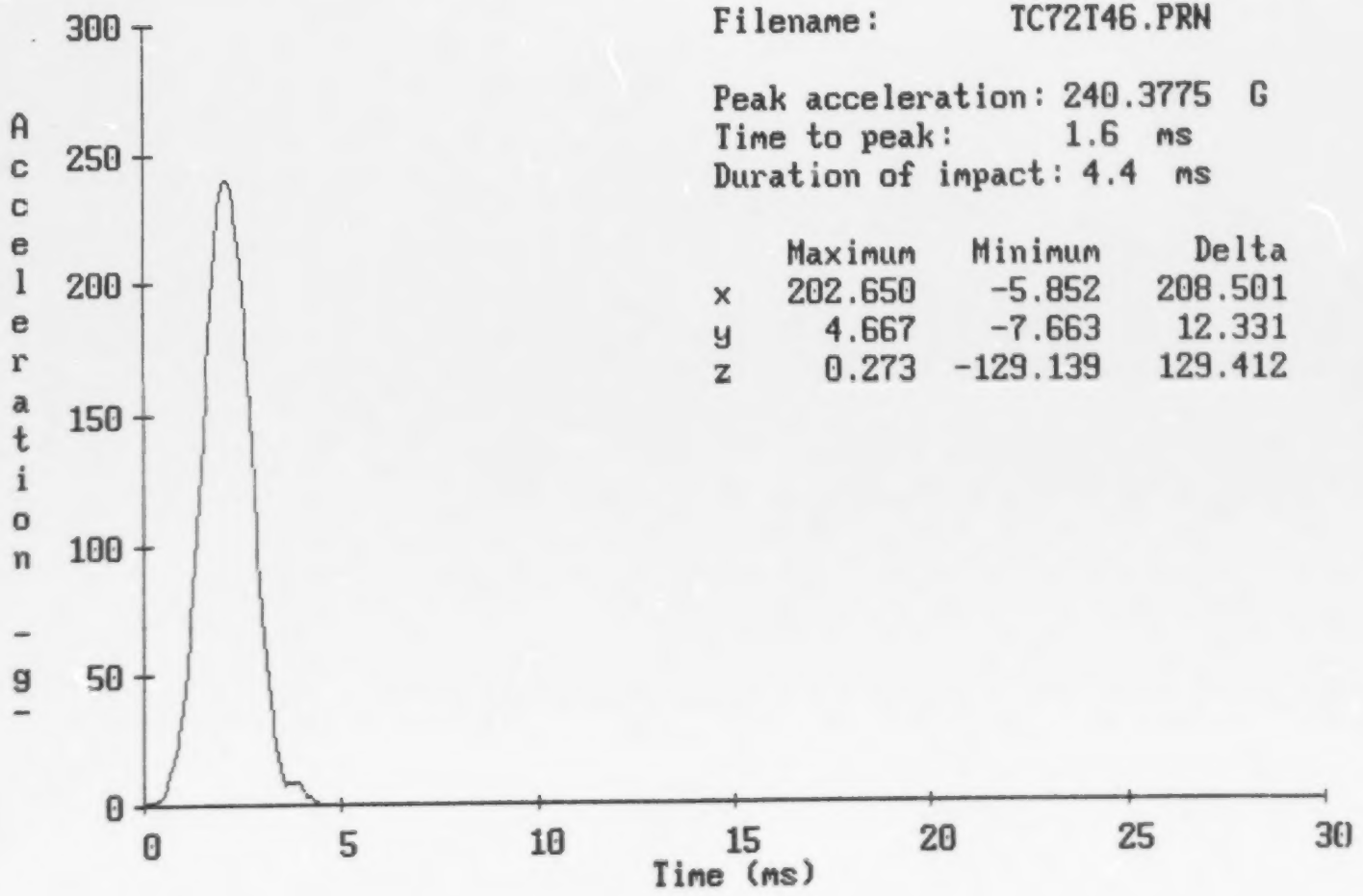
BIOKINETICS AND ASSOCIATES LTD.
HEAD DROP TEST
HYBRID IIIe

Preliminary Information:

Skull Serial No.: 007
Skin Serial No.: 419 B
Filename: TC72T46.prn

Date: August 16, 1989
Technician: T. Szabo

Test Parameter	Specifications	Test Results
Temperature	18.98 - 25.6 deg.	20°
Relative Humidity	10% - 70%	52%
Peak Resultant Acc'n	225 - 275 g.	240.4 g
Peak Lateral Acc'n	15 g max.	7.7 g
Is Acc'n Curve Unimodal?	Yes	Yes



Filename: TC72T46.PRN

Peak acceleration: 240.3775 G
Time to peak: 1.6 ms
Duration of impact: 4.4 ms

	Maximum	Minimum	Delta
x	202.650	-5.852	208.501
y	4.667	-7.663	12.331
z	0.273	-129.139	129.412

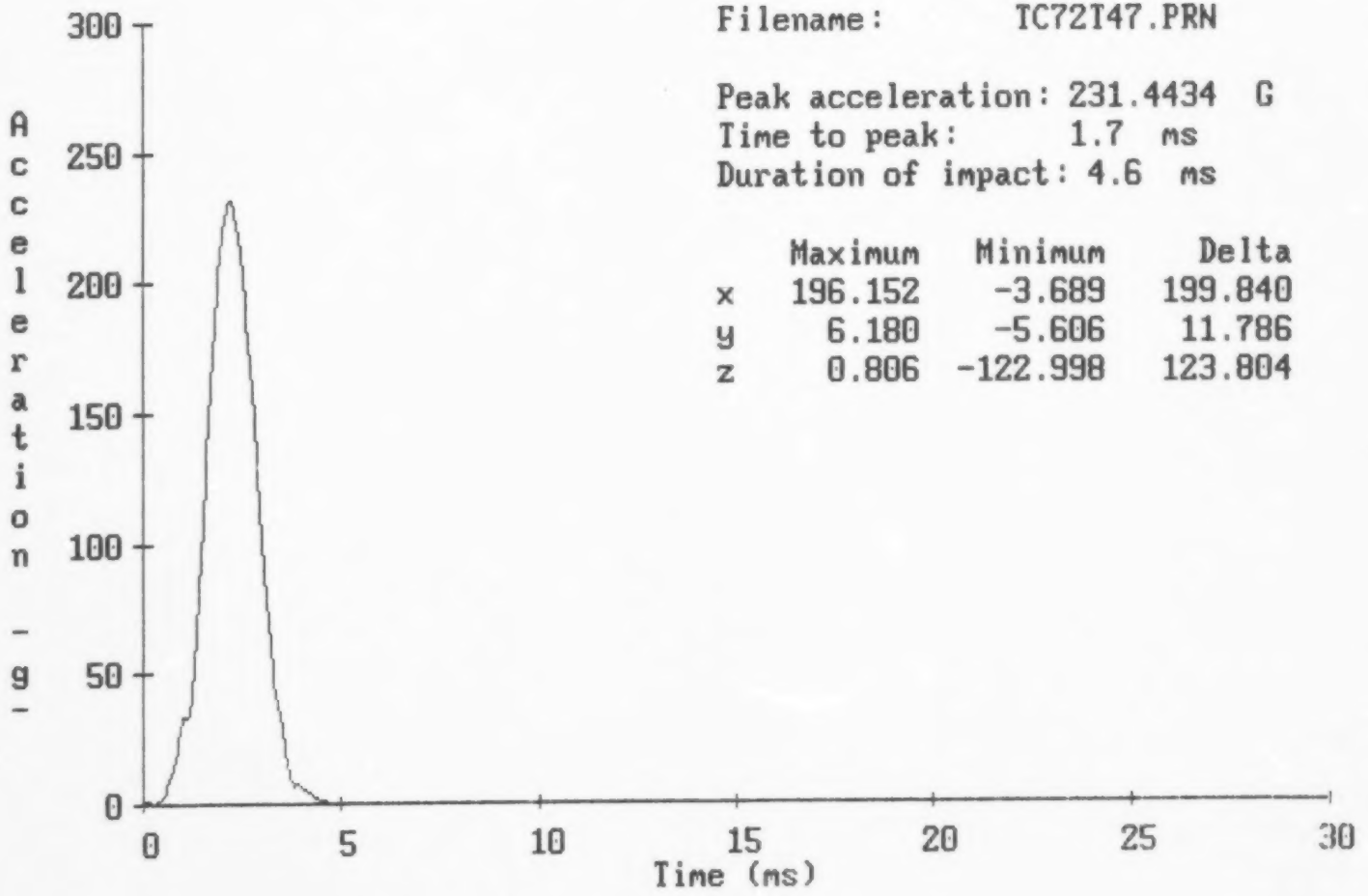
BIOKINETICS AND ASSOCIATES LTD.
HEAD DROP TEST
HYBRID IIIe

Preliminary Information:

Skull Serial No.: 007
Skin Serial No.: 436 B
Filename: TC72T47.prn

Date: August 16, 1989
Technician: T. Szabo

Test Parameter	Specifications	Test Results
Temperature	18.98 - 25.6 deg.	20°
Relative Humidity	10% - 70%	52%
Peak Resultant Acc'n	225 - 275 g.	231.4 g
Peak Lateral Acc'n	15 g max.	6.2 g
Is Acc'n Curve Unimodal?	Yes	Yes



Filename: TC72T47.PRN

Peak acceleration: 231.4434 G
Time to peak: 1.7 ms
Duration of impact: 4.6 ms

	Maximum	Minimum	Delta
x	196.152	-3.689	199.840
y	6.180	-5.606	11.786
z	0.806	-122.998	123.804